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60 CENTS

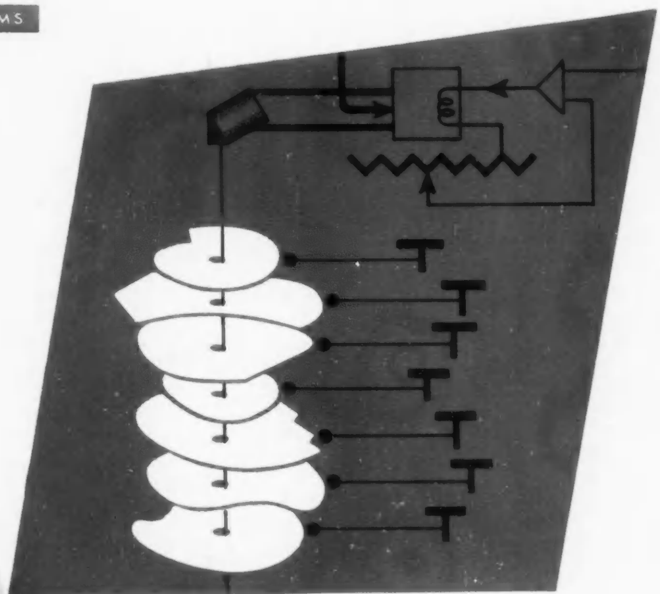
MARCH 1958

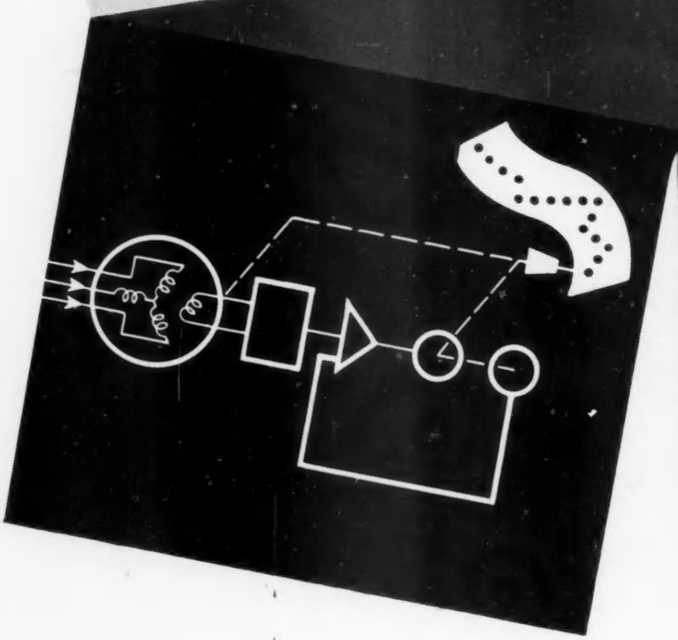
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

IDEAS AT WORK

Synchro Testing
Kiln Control
Function Generation





Control ENGINEERING

MARCH 1958
VOL. 5 NO. 3

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

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Continued on next page

Control ENGINEERING

DON GUMPERTZ, designer of the automatic warehousing system described on page 20, has been building electronic gear since his high-school days. As an eager ham operator, he made radio sets for others. Later, while holding down a four-day-a-week job, he began studying EE at the University of California. He left there in his junior year, however, for a chance to design ultra-high-frequency aircraft ground equipment at Air Associates, Inc. He went along with the first set sold to the first customer, Catalina Air Transport, as head of communications. Before setting up his own Industrial Electronic Engineers, Don was chief engineer at Aviola Radio & Radar Corp.

PRINT ORDER THIS ISSUE 35, 383

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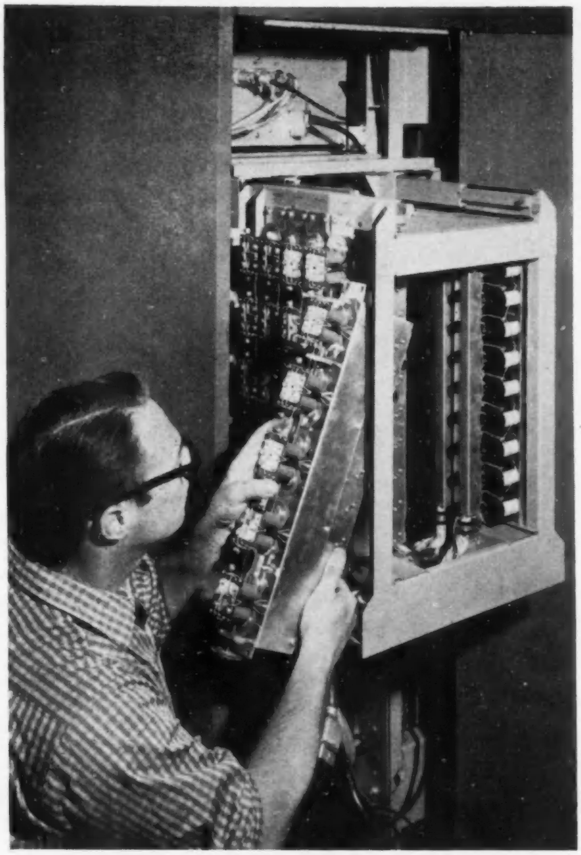

Model 1167 Pot Assembly slips out for easy access to components. Note independent clutches and fuses for each pot.

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SERVO SYSTEM...

Sets pots to the nearest turn of wire in less than three seconds

The new EASE* 1100 Series servo-set potentiometer system permits automatic adjustment of coefficient pots to a typical accuracy of $\pm0.008\%$ in less than 3 seconds average time. There are no dials to adjust, no meters to read, and almost no chance for error with the simple push-button selectors.

Heart of the system is a superior clutch design (patent applied for), the result of two years' field experience with servo-set pots. The new system uses no-drag clutches that disengage completely after setting, act independently of each other, and have an almost unlimited operational life. Tests show that these clutches far outlast the pots.

The Model 1166 pot system is an integral part of the EASE* DO/IT (Digital Output/Input Translator), which programs coefficients from punched tape and automatically operates and checks the 1100 Series computer.

Model 1166 servo-set pot system is another reason why the new Beckman/EASE* 1100 Series is rapidly assuming leadership of the analog computer field. For complete information on the computer and its components, please write Dept. L-3.

SPECIFICATIONS

Model 1166 Servo-Set Pot System

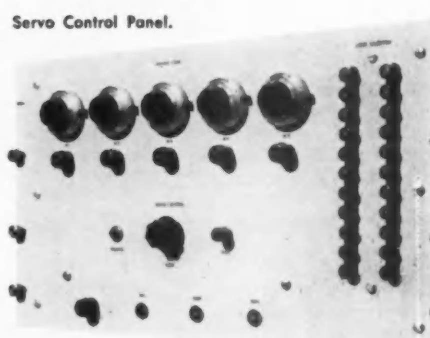
FRAME: 18" x 18" x 26". Mounts up to 10 Model 1167 Pot Assemblies (10 pots each). Includes two servo motors.

SERVO CONTROL PANEL: Contains Coefficient Selector; "Slew", "Null", and "Release" Controls; and five ungrounded manual pots.

POTENTIOMETERS:
100 Type A Helipots
Resistance: 50K $\pm5\%$
Resolution: 0.008%
Life: Exceeds 2,000,000 shaft revolutions

SERVO: Accuracy of Pot Setting: $\pm0.008\%$ typical, $\pm0.016\%$ maximum (within 2 turns of wire). Setting Time: Less than 3 seconds average; 5.2 seconds maximum, including release time.

Servo Control Panel.



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Richmond, California

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SHOPTALK

Window in Japan

This month CtE opens another window on the control world. In Japan, control engineer Kazuto Togino becomes our eyes and ears for technical coverage in that country, augmenting the news coverage furnished by McGraw-Hill's Tokyo Bureau.

Chief Researcher at the Government Mechanical Laboratory in Tokyo, Kazuto is a specialist in digital servomechanisms and data handling. He and CONTROL ENGINEERING first got together when Managing Editor By Ledgerwood started our world-wide survey on point-to-point positioning systems (the final installment begins on page 99 of this issue). Kazuto gathered the material for the report on the system developed by the Government Mechanical Laboratory. It was so good, By asked him to check other systems under development in his part of the world.

Panel at Work

Peering over the crowd in the picture here is Editor Bill Vannah (far right), who is sitting on a panel with former managing editor Lloyd Slater (at left), now director of the Foundation for Instrumentation Education & Research,

Princeton University's Prof. Earnest T. Johnson, and this month's *Control Personality*, Sy Herwald of Westinghouse's Air Arm Div. Subject of the discussion, at the Middle Atlantic Section of the American Society of Engineering Education: engineering problems raised by the practice of control systems engineering.

Editors on the Go

CtE staffers are looking forward to next month when a number of meetings will be out of the way and they can settle back to magazine deadlines again. Associate Editor Harry Karp is up to his neck as co-chairman of the New Jersey ISA's annual symposium (page 40); Editor Bill Vannah is doubling as program chairman for the ASME/IRD annual meeting at Newark, Delaware; and Sales Manager Russ Berg is assisting program chairman G. W. Heumann on the Automatic Control Techniques meeting sponsored by the AIEE, ASME, and IRE.

HOW ONE CONCEPT IN POTENTIOMETER DESIGN SOLVES THREE BASIC PROBLEMS

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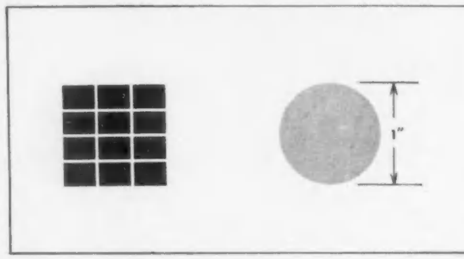
You can pack a lot of Bourns potentiometers into a small space—12 in one square inch of panel area (or 17 TRIMPOT JR.* units!) Fit them into corners, between other components, flat against chassis or printed circuit boards. Mount them individually or in stacked assemblies.



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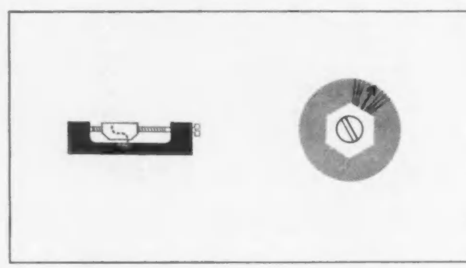
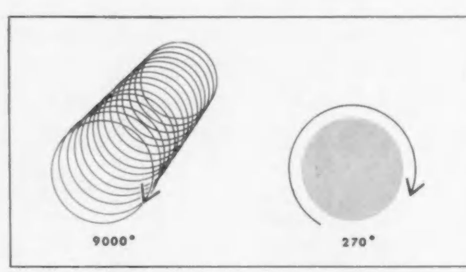
Bourns potentiometers are *self-locking* (no lock nuts required). Any adjustment *remains* stable. Shock, vibration or acceleration can't affect a setting. Bourns potentiometers are helping thousands of engineers make reliability a reality.



CIRCUIT BALANCING ACCURACY

Bourns potentiometers are 33 times as accurate as conventional single-turn rotary types—the screw-actuated mechanism provides 9000° of rotation instead of only 270°. Circuit balancing, calibration—adjustments of all types are easier, faster, more precise. And repeatability is assured.



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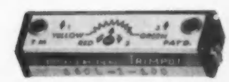

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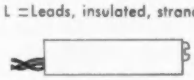
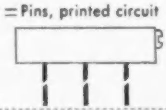
military and commercial units available in these terminal types:

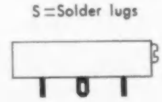
L = Leads, insulated, stranded



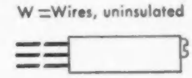
P = Pins, printed circuit



S = Solder lugs



W = Wires, uninsulated



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FEEDBACK

PROBLEM FORUM

Vital forum topics selected by readers this month are:

- **determining transient response from a phase-plane plot by the slopeline method**
- **organization of a systems engineering group for an oil company**
- **standards for industrial electronic control equipment**

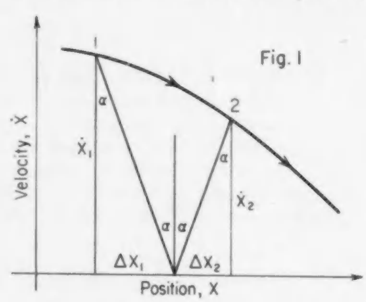
An educator, a chemical process engineer, and the chief electrical engineer for a machine tool company lead the discussion, and each earns an engraving of the Great Emancipator. Join in. Submit a problem or start a discussion of a topic that will spread some more knowledge across the control engineering field. Everyone learns while you earn.

A dynamic analysis kink

To the Editor—

Since Control Engineering has in the past published a series of articles on graphical solutions (Feb. '54 and Sept. '57 issues), I enclose this short "letter to the editor" for publication in your magazine.

Time can be determined quickly and to a good degree of accuracy from a phase-plane plot by the slopeline method. As illustrated in Figure 1,



to find the time starting from point (1), a line is drawn to the x-axis and then reflected until it intersects the phase-plane plot at point (2). The resulting two lines are inclined at an arbitrary angle α from the vertical as shown. The time that elapses between (1) and (2) is given approximately by:

$$\Delta t_{1-2} \cong 2 \tan \alpha \qquad (1)$$

The accuracy of determining this time increment increases with decreasing angle α. This evaluation happens to be exact if the portion of the curve between (1) and (2) is a straight line.

Equation 1 is derived as follows:

$$\Delta x_{1-2} = \Delta x_1 + \Delta x_2 = \dot{x}_{average}\,\Delta t_{1-2}$$

$$= \left(\frac{\dot{x}_1}{2} + \frac{\dot{x}_2}{2}\right)\Delta t_{1-2} \qquad (2)$$

But $\dot{x}_1 = \Delta x_1 \tan \alpha$, and $\dot{x}_2 = \Delta x_2 \tan \alpha$ (3)

Therefore Equation 2 simplifies to Equation 1.

Figure 2 illustrates the use of the technique to construct a transient solution from a phase-plane plot.

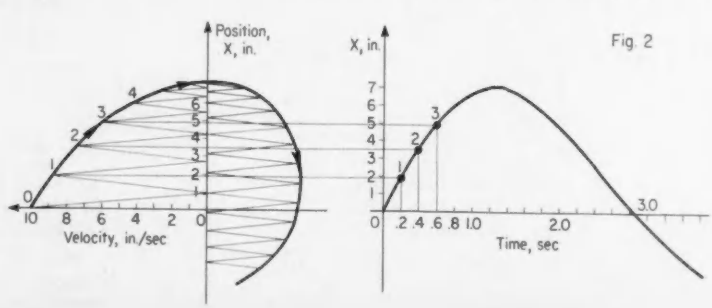
F. D. Ezekiel
MIT
Cambridge, Mass.

Systems engineering group

To the Editor—

Attached are some suggestions, prompted by Problem Forum, page 12 of the Nov. '57 issue, about a systems engineering group for an oil company. The ideas presented are my own.

A systems engineering group can



consist of one man, if he has a knowledge of the following subjects:

mathematics
electronics
servo techniques
practical hardware
practical systems
measuring methods
physics
chemistry
analog and digital computers

However, such a man is hard to find. Because of this, a systems group should consist of, say, three men with the following backgrounds:

- An electrical engineer with a good knowledge of electronics, servo- and control-techniques, mathematics, and computers, with some practical experience, and with a feel for physics.
- A physicist or chemical engineer with a good knowledge of mathematics, with practical experience and with a feel for electronics, control theory, and computers.
- An engineer with primarily a practical process-control background and a feel for control techniques and physics.

The object of the group is the analysis and synthesis of control systems. The best way for the group to approach problems is to break down processes into the most common basic building blocks. For instance, the oil refinery can be broken down into: (1) heat exchange equipment; (2) material transport; (3) material storage; (4) distillation equipment.

Then, the most simple general-valid formulas have to be determined, relating dynamics to physical dimensions. The validity of these formulas has to be checked by practical measurements. Their constants have to be corrected, or the minimum required measurements to obtain the dynamic data must be determined. This is a rather elaborate task, but once it is done, all problems can be attacked in an organized way.

In the oil refinery, the payoff of a systems engineering group will be in a better product, and fewer product losses because of scientifically justified design. For instance, pump-heads and control valves are at present chosen in a more or less arbitrary way.

J. E. Valstar
C. F. Braun & Co.
Alhambra, Calif.

Wants new standards, too

To the Editor—

In general I agree with what Bob Colten of the General Motors Technical Center says in his letter to the editor printed in the Oct. '57 issue (page 10). (See page 10 of the Feb. '58 issue for additional discussion of the

FEEDBACK

Colten letter.) I feel that the JIC Standards do not cover industrial electronic equipment in very great detail, possibly because at the inception of the standards industrial electronic equipment was more or less a rarity. Now that more electronics are being used in industry, I feel that some sort of standards are indicated to reduce confusion in installing and servicing the equipment and to maintain the quality of components used.

I have had very little personal experience in the use of industrial electronic equipment, but what few installations I have seen showed a need for standards of some sort to achieve uniformity of data, diagrams, and use of components. Each equipment builder evidently has his own standards and way of doing things, and the user of this equipment has to educate himself to the builder's system before he can fully understand and utilize his equipment.

Standards such as Mr. Colten is working on will serve to eliminate some of these different approaches to the design and building of electronic equipment and may help to unify the various schemes of presenting setup, servicing and operating instructions.

Raymond T. Fenn
Chief Electrical Engineer
New Britain—Gridley Machine Div.
New Britain, Conn.

Wants AIEE paper

To the Editor—

We are interested in obtaining a copy of the AIEE Conference Paper, Winter General Meeting, 1957, "The Transistor Nor Circuit Logic and Applications", by L. F. Stringer and W. D. Rowe, which was used as a reference to an article in the May 1957 issue of Control Engineering.

J. Elsley
Weapons Research Div.
A. V. Roe & Co., Ltd.
Manchester, England

AIEE is sold out on reprints of this paper. We suggest that you contact the authors: L. F. Stringer and W. D. Rowe, Motor & Control Div., Westinghouse Electric Corp., Box 2025, Buffalo 5, N. Y. Ed.

A compleat reader

To the Editor—

As I was reading my copy of the December '57 issue of Control Engineering, I came across your editorial, "Made, Not Born", page 69. I won-

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in JETEC 30 (TO-5 OUTLINE) Package

...the Industry-Standard Package

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2N398	105v	collector voltage		
2N404	12 m.c.	frequency cut off		
2N425	4 m.c.	frequency cut off	20v	V_{ceo} rating
2N426	6 m.c.	frequency cut off	18v	V_{ceo} rating
2N427	11 m.c.	frequency cut off	15v	V_{ceo} rating
2N428	17 m.c.	frequency cut off	12v	V_{ceo} rating
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FEEDBACK

der if the fifth word in the article was spelled incorrectly. The word is *compleat*. Could it have been spelled *complete?*

I enjoy your magazine and the new systems that are published each month.

Elmo W. Gibson
Ypsilanti, Mich.

If there is justification for a compleat angler and a compleat strategist, it seems to us that there is plenty of justification for a compleat control engineer. But thank you, Mr. Gibson. You delight us with your use of the possessive case when you refer to CONTROL ENGINEERING. Ed.

We have one, too

To the Editor—

We have noticed with interest the recent correspondence in *Feedback* (September 1957, page 16) concerning high-speed sampling switches.

This company has now completed the development of a unique rotary switch for use in the guided missile and allied fields. The basic principles and general engineering conception of the device, which enable it to operate successfully at rotational speeds in excess of 200 revolutions per second, were established by an original research program carried out by the Signals Research & Development Establishment of the Ministry of Supply.

The first version of the switch now being manufactured has a two-bank commutator system with 24 channels per bank, and can be supplied to run at speeds up to 220 rps.

R. E. Young
Sir W. G. Armstrong
Whitworth Aircraft, Ltd.
Coventry, England

Cheers. Ed.

Has remote controls; will fabricate

To the Editor—

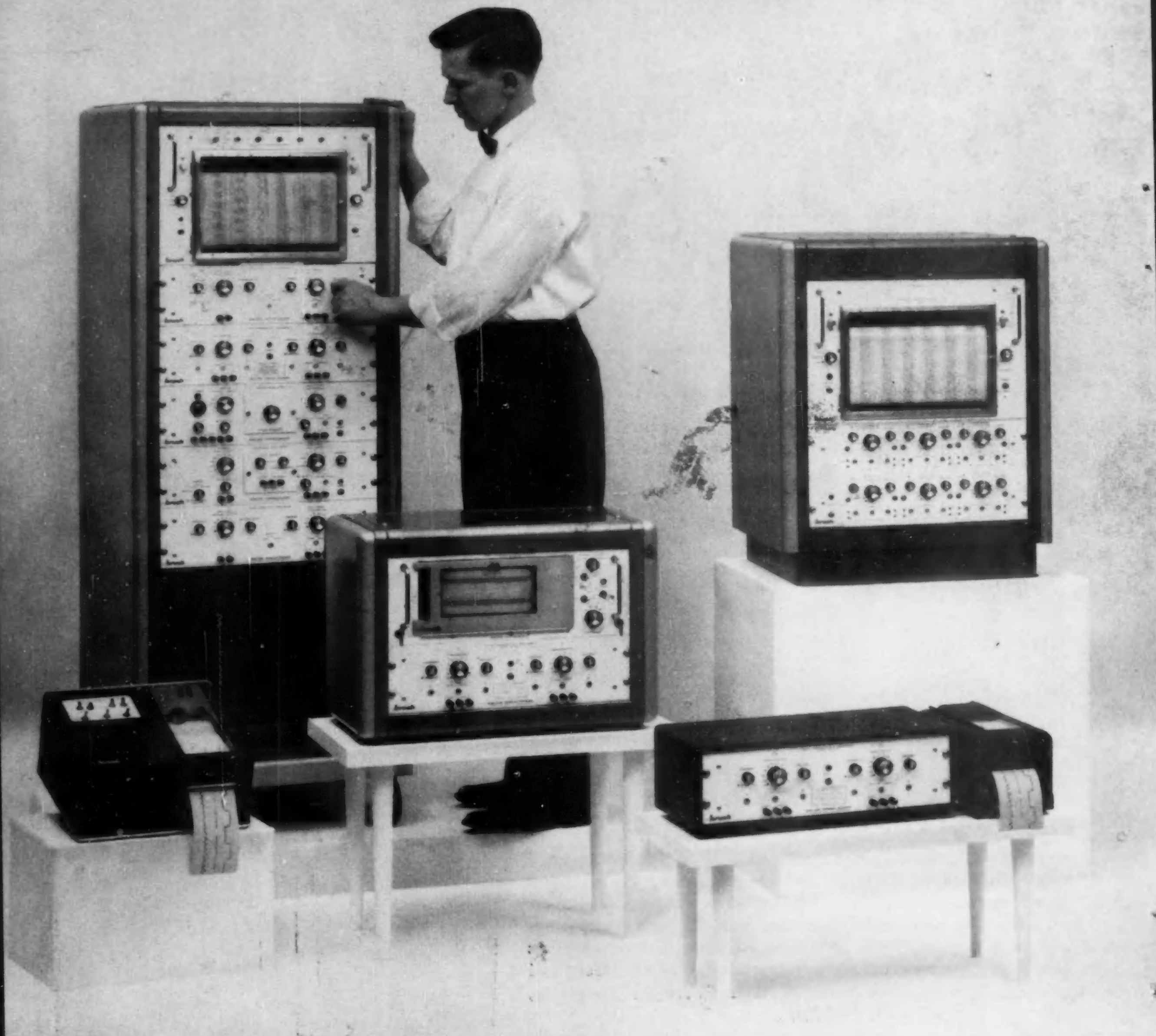
We note in your Dec. '57 issue Mr. J. Salvatore's article on a remote control for manual pots (page 107).

We have been building a Wheatstone bridge null balancing device using motorized controls similar to the device illustrated, and we would be quite willing to fabricate these units for commercial use if the demand is adequate and standardization were possible.

S. L. Sola
Townsend Engineered Products
Santa Ana, Calif.

IN DIRECT RECORDING SYSTEMS . . .

only—*brush* gives



When you need precise, permanently visible measurements of electrical or physical phenomena, make your logical choice of equipment from the newest Brush designs in *ultralinear* recording systems. For your specific application, now choose . . .

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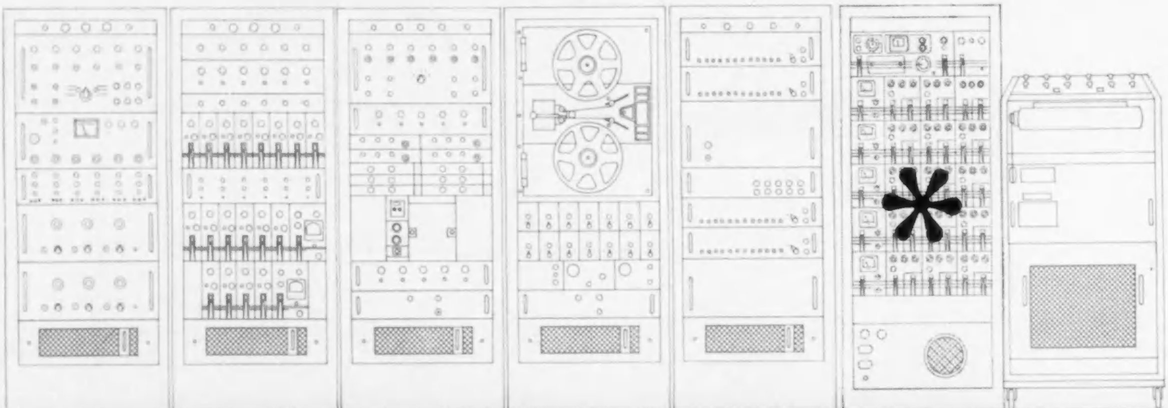


S. W. Herwald

jumps the artificial fences

One drizzly day in 1939, a young mechanical engineer, just graduated from the Case School of Applied Science, stepped off the train in Pittsburgh, took one look at the smoky, leaden skies, and fought down a sudden urge to jump back on the coach.

Lanky Sy Herwald had come to Pittsburgh filled with the idea of designing steam turbines for Westinghouse. His enthusiasm for the job finally won over the sinking feeling inspired by his first look at the steel city, and he decided to stay. But Herwald never got to do a turbine design. Recognizing an unusual engineering talent during a preliminary training course, Westinghouse promptly assigned him to its Headquarters Engineering Staff, which handled the tough problems that didn't seem to belong to any of the company's divisions.

One of those early problems was a feasibility study on how to control aircraft gun turrets. Herwald has been working with control systems ever since. Today, as manager of Westinghouse's Air Arm Div., he has had a hand in designing and developing a variety of automatic controls for both aircraft and missiles, including the defense system for the Navy's A3D fire control for the F4D Skyray, and the electronic target seeker for the Bomarc missile.

Back in 1939 on that first study, Herwald made, to him, a startling discovery: control system design was no place for a narrow specialist; it took knowledge in a variety of fields to make a complicated system work. To augment his own mechanical-slanted background, Herwald took electrical courses at Westinghouse, started night school at the University of Pittsburgh. There he earned a MSME, writing his thesis on gyros, stuck to it until he had a PhD (major: engineering mathematics; thesis: servomechanisms).

During World War II, Herwald worked on a variety of servo and control problems, mostly applied to aircraft. He was among the engineers that maintained gyro-stability was required for any tracking system. One stickler that persisted was how to automatically compute lead time for turrets. The Westinghouse group never reached a fully automatic system; by the time they had something, the war ended.

But that didn't end Herwald's work on control systems; rather, it was the start of real systems work. In 1945 he was involved in solving networks with electromechanical computers; then he was back on aircraft controls, this time specializing on tracking systems. Here the emphasis was first on optical; then electronic, and finally on infrared techniques.

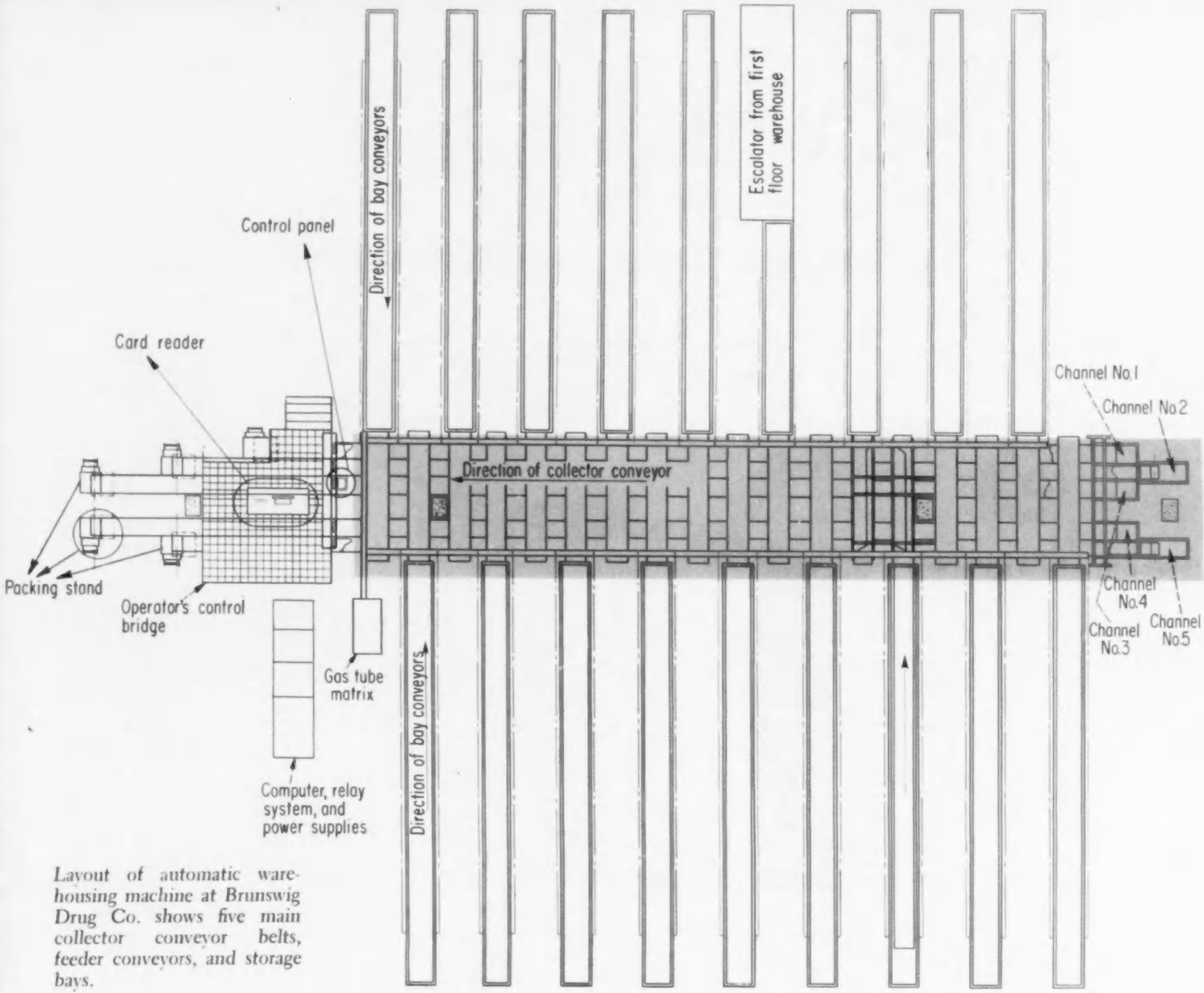
Although Herwald won a reputation at Westinghouse as a top-notch servo specialist, he would much rather be known as a good control engineer. He continually urges his engineers to "knock down the artificial fences". He says, "For a good control engineer, there's nothing out of line; you have to be able to move into any field: hydraulic, mechanical, electrical, electronic, or thermal."

Herwald (left) and science student.

Herwald thinks the broad view is even more important today, but it's got to be tempered. "We're closing bigger and bigger loops. We're using information on what's happened to control what's going to happen. But we're doing so much broad system analysis that we ignore the detail analysis. You find an engineer designing a magnificent weapons system and it turns out the system won't work because the designer didn't know how the parts functioned. Building a complicated system also involves making decent gearboxes, building a good synchro, and using components properly."

That's why Herwald continually exhorts his engineers to "get their hands dirty, to get to know components". No stickler for office formality, the likable Herwald is a familiar sight bounding around the big Air Arm plant. But he's a strong advocate of real professionalism for his engineers. At Baltimore, an engineer has his choice of moving up the ladder in pure engineering or in administration. Herwald says, "Every managerial job here has an equivalent—in dollars and prestige—with a purely technical position."

Despite the heavy work-load Herwald makes time for relaxation. Until recently he was an ardent member of the plant softball team ("You haven't seen anything until you've seen Herwald flapping around the bases," chuckled one Air Arm engineer). And he tries to find some time to impart a little scientific background to his three children. As he puts it, "Everybody should know a little science today, because in a democracy better than half the people have to be able to understand what's going on to make sensible decisions. We'll get the truly scientific-oriented people—the ones with real interest in science—but we won't be able to make the right kind of decisions unless everybody understands a little bit." Here, too, the good-humored Herwald likes to jump over the artificial fences.



Layout of automatic warehousing machine at Brunswig Drug Co. shows five main collector conveyor belts, feeder conveyors, and storage bays.

Punched Cards Run Warehouse

Automatic controls fill orders at rate of four per minute, pulling stock from an inventory of 1,600 items. Products handled range from a package of razor blades (the smallest) to a 9-in.-wide box of diapers (the largest).

In Los Angeles last month, an unique automatic order-filling machine passed its fast checkout test started picking and filling drug orders at a rate of one every 15 sec. Designed by Industrial Electronic Engineers and designated RVS Mark I, the order-assembling system has been installed at the Brunswig Drug Co. in Los Angeles, where its punched-card control permits rapid selection from a stock of 1,600 different products.

One of the things that makes this system unusual is that it's built as a machine that can be installed in most warehouses. The key parts (see drawing above):

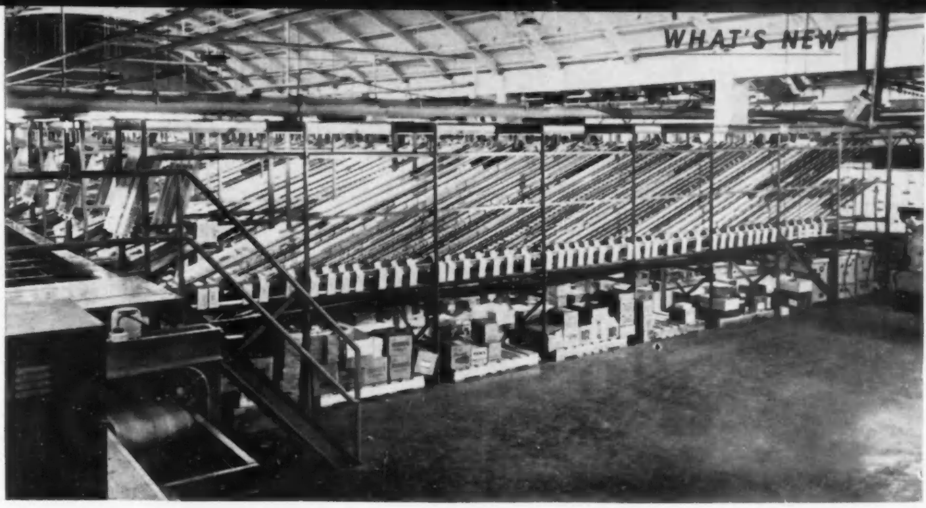
▶ five main-line collector conveyors that run through the center of the machine and deliver the goods to five packing stations, one at the end of each conveyor.

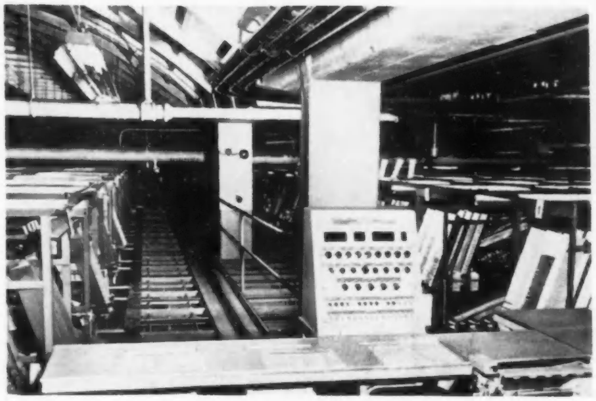
▶ 18 bays containing merchandise arranged perpendicular to the collector conveyors. Under each bay (there are nine on each side of the collector conveyor) is a feeder conveyor that carries the goods from the bay to the main collector belts.

▶ a control system consisting of a special-purpose magnetic drum, digital computer, relay switching system, and a card reader for input information.

Here's how the system works. Orders, received by mail or phone, are sent to a tabulating room where quantity and item are punched on cards. Twenty or 30 orders of the

Here's how storage bays with feeder conveyors underneath send products to main collector conveyor. Extra storage of items is carried on under individual bays. Each chute contains at least an 8-hour supply of the commodity.





Control console indicates order number being filled; it is located so that operator can look down warehousing machine.

Closeup of solenoid dispenser (preceding chutes have been removed) as it drops products onto feeder conveyor.

same class are stacked together, along with associated paper work, and then sent to the warehouse control console. The machine operator feeds the deck of cards into a reader while he keeps the printed paperwork in front of him on the desk. Then he presses the machine start button.

• **Pick a channel**—The machine first automatically selects a collector-conveyor channel, indicating its choice on the console. Then it starts dispensing the required number of each item on the order. To do this, a signal is sent to the solenoid-operated dispenser mechanism at the bottom of the proper chute in the merchandise bays. Since the chutes are inclined at an angle of 20 deg to the horizontal, the merchandise drops out onto the feeder belt when the self-locking dispenser mechanism operates. And it operates once for each unit ordered (six times for a half a dozen, 12 times for a dozen, etc.) The merchandise drops from the chute 6 in. onto the feeder conveyor, which crosses over the top of the collector conveyor. A system of diverter gates is operated also by the computer to send the merchandise into the previously selected collector conveyor.

Close to each dispenser mechanism is a sensor or "feeler" switch, operated by the merchandise as it moves past. This mercury flipper switch reports back to the computer to verify that the items ordered were actually dispensed, and in the right quantity.

At the end of each collector conveyor is a stop gate operated by the computer. When one order is dispensed to the packing stand, the stop gate closes, allowing another order to be filled in the same collector channel. Order packing is done manually. The order packer signifies his readiness for another order by pressing a pushbutton at his station.

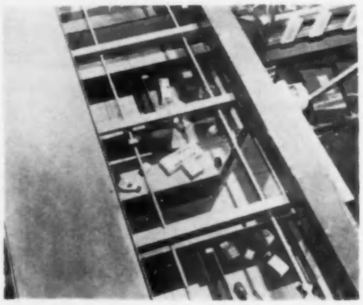
• **Paperwork follows along**—Back at the machine control, the console shows the order number being filled, and which of the conveyors is involved. The operator picks up the paper work for an order, notes the channel on which it is being filled, and drops the papers down a chute so that it arrives at the same packing station as the order itself.

When the machine completes filling the first order (it takes an average of 15 sec) it immediately selects a second channel, starts processing a second order. The machine fills orders in this way until it runs out of cards.

Although the warehouse stocks 1,600 individual items (in less than case lots) and 200 multiple packs, the machine dispenses only 160 commodities in any given order. If the order has more than that number of items, it is treated as two (or more) separate orders. And the machine can dispense up to 99 units of any commodity.

• **Stepped up capacities**—D. G. Gumpertz, president of Industrial

WHAT'S NEW



Diverter gates, operated by the computer, move products from feeder conveyors onto proper collector conveyor traveling below.

WAREHOUSE . . .

Story starts on page 20

Electronic Engineers, says the control system is capable of handling 10,000 different commodities, can process 1,032 commodities on a single order. But it has been toned down to handle Brunswig's particular problems.

Gumpertz also says the warehousing equipment can work with a variety of commodities: cosmetics, automobile parts, groceries, electronic components, etc. For some of them, he says, changes in design are required. For example, if the system were to handle bottled goods, ejector mechanisms might have to be redesigned and the height of the drop from chute to feeder belt lessened to prevent breakage of glass.

The IEE president estimates that it would cost $200,000 to reproduce the Brunswig installation. It's expected that the drug company will amortize the machine in three years. Gumpertz is ready to offer other units in prices ranging from $40,000 to $250,000. There are three basic models: one is a high-speed unit similar to the Brunswig installation; a second is an intermediate machine that operates at a much slower rate; and the third replaces the card reader with a hand keyboard on which an operator punches in the order. It can handle up to 200 items and fill about 100 orders per day.

• People out-error the machine—A Brunswig spokesman said that his company's experience with the machine so far indicated that maintenance should not be a serious problem. He also said that errors have been cropping up, but that the majority of them have been traced back to employees rather than the machine.

Typical mistakes: stocking the wrong item in a chute, tabulating the wrong commodity on the punched card, accidentally dropping merchandise on the collector conveyor while an order is being filled.

The machine is said to operate with an error rate of 0.1 percent. So far it's done a good job of catching most of its own mistakes. It also alerts the operator if an ordered item is out of stock or if the order is only partially filled, reporting exactly how many items have gone into the partially filled order.

Brunswig can increase the size of its inventory merely by adding storage racks and extending the collector conveyor belts. Units up to 6 in. by 8 in. by 9 in. can be handled now. A box of diapers is the biggest item actually dispensed. The smallest: a package of razor blades.

Disc Memory Does Warehouse's Thinking

400 miles north of the Brunswig Drug Co. another warehouse was making news last month. At Factory Motor Parts, Inc., of San Francisco, an IBM RAMAC—computer and memory—started performing this auto-supply company's inventory control and customer billing.

Built around a disc memory unit resembling a stack of large phonograph records, the IBM 305 RAMAC has a memory storage capacity of 5 million characters. It has been installed in a warehouse that stocks over 23,000 items and serves more than 2,500 customers.

When an order for an auto spare part is received, the machine first determines if the part is in stock and if it has been superseded by an improved model, then its location in the warehouse and other information needed to print out the shipping order and warehousing "picking ticket".

At the same time, the computer-memory automatically prices the item, computes necessary discounts and sales taxes, and then runs a routine credit check on the customer. It also continually analyzes sales trends to determine best stock levels.

With the new equipment, a Factory Motor Parts spokesman said, an order can be filled and on a truck within an hour of its receipt.

Electronic Chevrolet

At the General Motors Technical Center one day last month, a 1958 Chevrolet cruised down a specially prepared road. What made this event unusual was the fact that there was no human driver at the wheel. Instead, a small analog computer and a servo system steered the car, following a magnetic path. Producing this path was low frequency ac power coursing through a cable buried in the road.

To Dr. Lawrence R. Hafstead, vice-president in charge of GM research, the driverless Chevrolet represented "the hardware phase of a system demonstrated in model form in 1953 by RCA". Since then, RCA has set up a test strip near Lincoln, Neb. and used it for a signal system. Now GM is taking the signals from the road and putting them through specially designed equipment to steer a full-size passenger car.

The equipment Hafstead meant starts with a pair of tuned pickup coils on the front bumper of the test vehicle. These straddle the magnetic path. Since the voltage across the terminals of the coil depend on the strength of the magnetic field, any deviation or lateral motion of the car causes a difference in voltage from one pickup coil to the other.

These voltage variations feed into a small electronic analog computer mounted on the instrument panel. The computer measures the difference in voltage, then sends a signal to the servo system to position the front wheels and correct the error signal.

Although nobody at GM is ready to predict that the computer-controlled car will be the Chevrolet of the future, the auto executives did point out that steering control might be just the first step of a really sophisticated system "for controlling vehicle spacing, detecting location of cars, or giving the driver signals for throttle and brake control".

The electronic Chevrolet also had one other piece of equipment worthy of mention: a switch to turn off electronic control when passing other cars and making turns at intersections.

FIER Posts First Year Accomplishments

Just before the 1956 ISA show, ISA established the nonprofit Foundation for Instrumentation Education & Research. Then in February 1957 Lloyd E. Slater left his post as CtE's managing editor to become FIER's first executive director. Last month, executive director Slater reported on the foundation's first year in business. He diagnosed normal growing pains, offset by some solid activity.

Like most foundations, FIER's first job is to win the confidence of people, companies, and groups that might contribute funds for educational purposes. The infant has to convince such tough evaluaters as the National Science Foundation, for example, that FIER's projects are soundly conceived, are capable of good management.

In 1957, FIER launched these projects:

- Biomedical conceptual clinic—instrument designers and biomedical researchers met to study medical instrumentation problems.
- Food analysis conceptual clinic—on-stream analysis of food processing was discussed by instrument designers and food industry engineers.
- FIER/ISA fellowship at Case Institute of Technology—in instrumentation.
- Aeronautical research award of $1,200—made to Stanford University in behalf of the North Texas Section of ISA.

For FIER's second full year of operation, Slater is overflowing with plans. Currently being activated is a three-week summer school in instrumentation and process control for post-high school institute instructors, a conceptual clinic on metal-working instrumentation, tentatively scheduled for June, and for later in 1958, a technician job analysis survey to be run jointly by FIER and ISA.

Explorer Reports

Around the world, 12 Minitrack stations and 6 Microlock stations are keeping tabs on the U.S.'s first satellite, Explorer. Minitrack (CtE, Dec. 1957, p. 22) is the primary system for tracking; Microlock is a backup measure being run for the Army by the Jet Propulsion Laboratory of the University of California.

Explorer sent out its scientific information signals both in tone modulation and phase modulation. The telemetered data was recorded on magnetic tapes at the various Minitrack stations. The tapes were first sent to the Jet Propulsion Laboratory, and then are forwarded to research centers conducting the various experiments. For example, the University of Iowa is receiving cosmic ray information.

It's expected to take up to 8 months before these telemetered reports have been analyzed. Then, they'll be ready for transmission to IGY world data centers, where other nations will have access to the data.

The Kiev—an All-Purpose Computer

VIENNA—

Russian scientists are assembling a new universal computer at the Ukrainian Mathematic Institute, according to reports reaching here. Called the KIEV, the machine has been designed to control processes at chemical, metallurgical, and oil-refining plants and to solve a wide range of scientific and engineering problems.

As a computing-controller, it is said, the new computer will set the optimal mode of operation of a blast furnace (for example), taking into consideration the quality of the ore, coke and, sinter cake. Once it has set operating guides, the computer keeps an eye on the process, maintains the mode set and then signals when the pig iron is ready for tapping.

Developed by Ukrainian scientists under the direction of Boris Gnedenko and Prof. Viktor Glushkov, the KIEV is capable of performing about 7,000 operations per sec. All its units—including the digital, the storing, and other elements—operate on different frequencies to facilitate adjustment. Widespread use of semiconductor units has improved reliability, according to the Russians. And the standard elements out of which it is made can be used for the assembly of various special-purpose computers.

New Boiler Controls

Although electric utility companies are concentrating on computing control for efficient distribution (see page 73), they haven't neglected boiler controls completely. Dayton Power & Light, Metropolitan Edison (Reading), and Philadelphia Electric Co. will place once-through boilers in operation this year. Each will be equipped with an L&N direct-energy-balance combustion control system.

NOW! END READOUT CONFUSION...

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FIRST OF A COMPLETE LINE OF DIGITAL INSTRUMENTS! Others include: Converters for measuring AC, ohms, ratios...multiple input scanners... serial converters to drive typewriters and punched tape units.

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CLEAR AND SHARP, ANY WAY YOU LOOK AT IT

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SPECIFICATIONS

Display...Four (4) digit with automatic polarity indication and decimal placement. Total display area 2" high x 7.5" long, internally illuminated. Individual digits 1.25" high.

Automatic Ranges...0.0001 to 999.9 volts covered in four ranges.

Accuracy...0.01% or 1 digit, whichever is larger.

Counting Rate...30 counts per second, providing average balance (reading) time of 1 second, maximum balance time of less than 2 seconds.

Reference Voltage...Chopper-stabilized supply, referenced to an unsaturated mercury-cadmium standard cell.

Input Impedance...10 megohms, all ranges.

Output...Visual display, plus print control. Automatic print impulse when meter assumes balance. No accessories required to drive parallel input printers.

Input...115 volt, 60 cycle, single phase, approximately 75VA.

Dimensions...Control unit, 5¼" high x 19" wide x 16" deep. Readout display, 3½" high x 19" wide x 9" deep.

Weight...Approximately 40 lb.

Price...$2,100

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A Division of Cohu Electronics Inc.

Automatic Pilot Plant . . .

uses electronic instruments, on-stream analyzers, and computer-control to cut experimental errors and to speed up testing. But its biggest advantage may be providing information about processes.

A continuing project for many control engineers in the process industries is understanding what goes on in the complex processes they have to control. Engineers at the Esso Standard Oil Co.'s Bayway (N. J.) refinery expect to learn a lot more about refining when a computing-controlled pilot plant is installed this spring.

Called the Micro-Plant, the new equipment was designed by Consolidated Electrodynamics Corp. It's a far cry from a conventional pilot plant Micro-Plant permits quick changes in process conditions because it uses electronic controls and needs only eyedropper quantities of products because it relies on on-stream analysis instrumentation. A digital computer automatically programs a test, monitors temperature, pressures, flows, and gas and liquid stream composition,–and, in some cases, logs out the data.

Esso will try out this new equipment on a catalyst improvement project. The company is trying to work out better catalysts for its Powerforming process. That's a reforming process that changes the molecular arrangement of low octane paraffin and napththene to high octane aromatic hydrocarbons. By using Micro-Plant the company expects to decrease experimental error one-third, to cut the number of runs in half.

At Bayway, the new pilot plant will fit into three cabinets, barely enough to cover the wall of a small office (a major change from the conventional pilot plant that frequently is a sprawling maze of pipes, instrument connections, and gages). The input system, in the first cabinet, accurately meters five or six different liquids or gases fed to the reactor–which is in the second cabinet. The third cabinet will contain the product recovery system that collects and separates the various products from the reactor, measuring their volume and weighing them to an accuracy of 0.1 percent.

Both the service and product recovery systems are general-purpose units, designed to handle a wide range of catalytic processes. The reactor, too, can be easily changed to suit the process.

In running a test, engineers first program the computer–a Royal McBee LPG 30. That means deciding such questions as how long to run the plant, how long to stay on a given phase of operation, and what operating conditions to use. Once the program's inserted, the computer takes over.

It starts off by automatically pressure-testing for leaks. Then it runs the test. The program probably would include an oil cycle, a regeneration cycle, a catalyst treating cycle, and a shut down cycle after a specified number of complete cycles. If an uncontrolled condition is detected – one which is outside preset limits–the computer automatically shuts down the pilot plant.

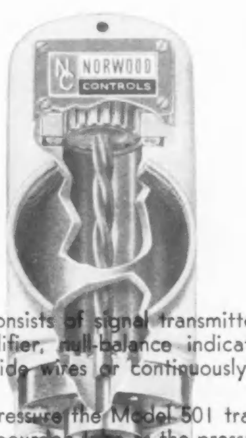
On-stream-analysis is made possible by the use of seven different kinds of instruments. These are located both in the input and in the product-recovery sections. In the product-recovery section, on-stream chromatographs furnish product-composition data. Two of these, vapor-liquid partition devices, analyze all liquid hydrocarbons boiling up to 325 deg; a third chromatograph analyzes the gas stream for hydrogen and C_1 through C_5 hydrocarbons.

During regenerations, oxygen is measured by a Hayes paramagnetic analyzer; hydrogen by a CEC thermal conductivity analyzer; carbon dioxide by a Mine Safety Appliance infrared analyzer; and water by a CEC moisture analyzer.

Data from all these instruments flows back to the computer, where selected data is typed out automatically in a predetermined format. During long tests, an engineer can check the pilot plant at any time and be "told" what phase the test is in, which valves are open, and what information is operating the system. And he can also call for a printout of what information the run has accumulated so far.

Esso expects a big payoff on its new automatic pilot plant despite its high

why?



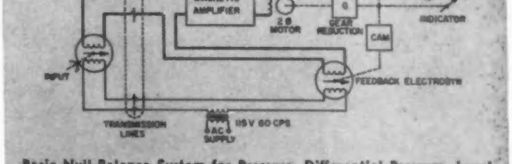
Basic system consists of signal transmitter, magnetic servo amplifier, null-balance indicator. (No electron tubes, slide wires or continuously moving parts.)

In measuring pressure the Model 501 transmitter utilizes a twisted bourdon tube as the pressure sensing element. This tube converts the pressure into shaft rotation of the ElectroSyn signal generator, a rotary differential transformer. The 8½-volt signal output from the ElectroSyn signal generator is an a-c voltage exactly proportional to the measured variable. Write for ElectroSyn Brochure B257 — **Norwood Controls Unit, Detroit Controls Division, 938 Washington St., Norwood, Mass.**

More and more leading pipeline companies are choosing

NORWOOD CONTROLS ELECTROSYN SYSTEMS

to measure and indicate operation pressures and flows, and for digital telemetering...



Basic Null-Balance System for Pressure, Differential Pressure, Level

because ElectroSyn offers:

- **Higher reliability**
- **Lower maintenance**
- **Flexibility of application**
- **Rugged electro-magnetic system**
- **Can withstand static overload of 300% of rated pressure for a 1% zero shift**
- **Remote transmission**
- **Explosion-proof transmitters**

AMERICAN-Standard

DETROIT CONTROLS DIVISION

price tag, $250,000–10 to 20 times the cost of a conventional unit. Most of the saving stems from shortcuts in time. But the biggest advantage may be in new information about processes. Esso thinks the new automatic pilot plant may show the way to some long-time oil-industry goals. One Esso will work on: an on-stream chemical test for octane rating to replace the empirical engine test.

New Computer Subsidiary Stars in R-W Self-Appraisal

With the sale of the first RW-300 tucked in the order book (CtE, Jan. '58, p. 44), executives of Ramo-Wooldridge Corp. gathered in New York to talk to the press about the industrial future of that fast-growing company in computing control. On the agenda: two hot commercial subjects.

Subject number one was the formation of Thompson-Ramo-Wooldridge Products, Inc., as a wholly-owned subsidiary to make and market digital computers (and possible future products) for process control. Subject number two: how the "new" company sees the future of computing control.

Joseph F. Manildi, general manager of TRW, bore the brunt of the technical aspects of the discussion. Said Manildi, "I'll be pleased if we sell 12 systems using the RW 300 in 1958." Manildi also told the group that the company would continue the policy of conducting free study proposals for prospective customers.

Although there's been only one concrete sale announced to-date, the company has conducted studies in a variety of industries. Manildi claimed that in every application examined, the equipment would pay for itself in from less than one year to three years maximum. He also tossed out some other "ball park" figures. Installation cost of a digital computing-control system ran from a fraction of the cost to ten times the cost of installing conventional instrumentation, depending on the process. In cement making, for example, the cost ran the full ten times.

• **Goal is 500 hours**—Answering a question on reliability, Manildi said the company was shooting for 500 hours of continuous operation between failures.

Harold George, senior vice president of Ramo-Wooldridge, substituted for President Dean Wooldridge,

who is also president of the newly-formed TRW, Inc. George told the group that R-W's sales in 1957 passed the $42 million mark (capping one of the most fantastic rises in recent industrial history: in 1954, the company's sales were $1 million, in '55, $10 million, in '56, $29 million). Of the $42 million, over 90 percent represented sales to the military.

Before the meeting, George confided that TRW would soon be able to announce the sale of two more RW-300's for process control. One will go to a cement manufacturer on the West Coast, the other to a major chemical company for installation in a pilot plant. Overseeing production of these, and all other RW-300's to come, is TRW's new vice-president for manufacturing, Irwin A. Binder, formerly assistant general manager of Thompson Products' Tapco plant.

Yugoslavs Plan Numerical Control

The first numerically-controlled machine tools to be built in Yugoslavia are on the boards of two Yugoslav companies: Radioindustrija and Prvomajska. According to proposals, the former will produce the electronic equipment, the latter, the machine tools themselves.

Already under way is design work for prototypes for the following tools: an electronically-controlled copying lathe, an electro-erosion metal-working machine with electronically-controlled distance regulation and water supply, and an ultrasonic-wave-controlled boring and grinding machine capable of grinding the hardest materials used in production.

Computer History Book

Visitors to the 1958 Brussels World Fair—which opens next month—will see a computer history book in action. IBM has turned its 305 RAMAC random access disc memory into a history book by recording in 10 languages the most significant event in each year since the birth of Christ. Covering 1,962 years, because historians now believe that Christ was born in 4 B.C., the memory book prints out a chosen event in less than a second. A visitor can select a year and then read the significant event of the year in his preferred language.

To make the historical file, many scholars studied over 50 sources. The

toughest job, according to IBM, was finding data on the years prior to the Renaissance, a period that is poorly chronicled. Once the outstanding event for a year was identified, it was put into a statement of 100 characters, translated into 10 languages.

The 100-character limit represents the capacity of a single channel of RAMAC's buffer drum. The almost 2,000 statements in 10 languages require less than 2 million of RAMAC's 5-million character capacity.

The important happening for 1957 is the launching of Sputnik I.

Computer Abstracts

Still another unusual job for a computer was unveiled by IBM last month. This one had more meaning for technical men: computer abstracting of technical and scientific articles.

Reporting at the annual meeting of the AIEE, IBM researchers told how they had programmed an IBM 704 Electronic Data Processing System to scan a technical article and to identify its main significance.

To do this, the article is first punched out on cards, then transcribed to magnetic tape which is fed to the computer. Incapable of intellectual comprehension, the computer treats words as physical entities. It determines their significance by measuring the frequency with which they are used individually and the frequency of combinations and couplings.

After the article has been scanned, word usage and placement undergoes a statistical analysis from which a table of values is made. The machine then analyzes each sentence based on this table and awards a significant factor to it.

It will select, on the basis of the degree of these factors, the several highest ranking sentences and print them out. If the significance is very high, a single sentence might serve as the entire abstract. If, on the other hand, the meaning is strung out in several sentences, the machine will print out all of them.

One big advantage of machine abstracting, the researchers pointed out, is that only original statements of the authors appear in the final abstracts. There's no chance for misinterpretation by human evaluators.

However, IBM cautioned that the system still had a number of "bugs" in it. For example, the machine can be "fooled" by an article that supplies a lot of background information.

push down, pull up...and it's all-set!
new "snap-in" FLOWMETER
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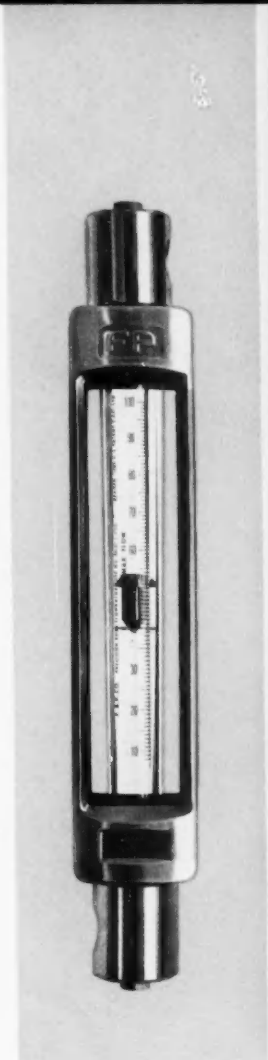

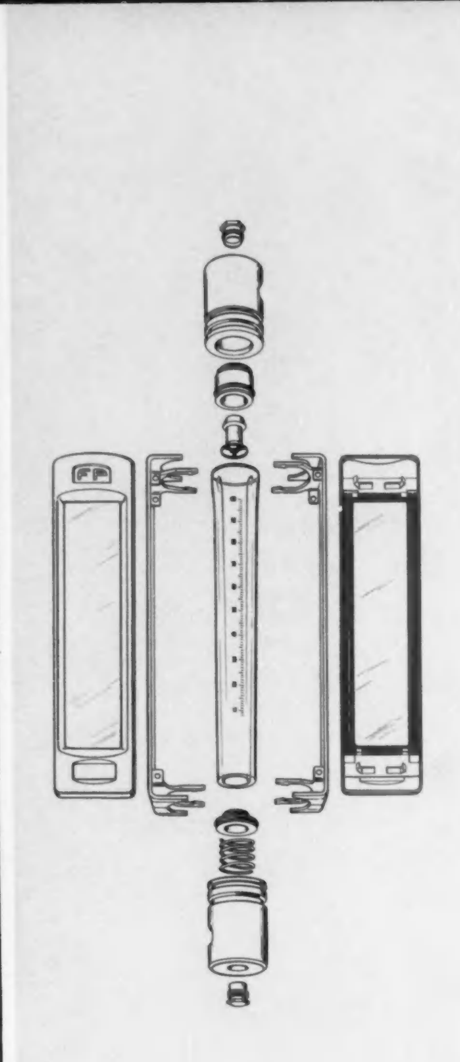

The ultimate in simplicity, the F & P 2700 Series Flowrator meter marks the first major advance in variable area flowmeter design in many years. Inserting the metering tube is a real snap. Just push down, pull up . . . and it's all set! And the tube can be removed just as easily without disconnecting the meter from the pipeline. The only tools required are your hands.

How's that for simplicity? No stuffing box . . . no packing gland . . . no screws, no bolts, no adjustments. Even the face and side plates "snap" in. Special O-ring construction gives quick, sure seal . . . resists corrosion. "Floating" between the end fittings, the tube is completely isolated from pipeline stresses. This fully field tested design withstands even *higher* pressures than conventional stuffing boxes. The 2700 Series can be supplied in a variety of corrosion-proof materials, and complete accessory equipment is available. Dimensions are those recommended by ISA RP-16.1 (tentative), for both threaded and flanged meters.

In addition, the 2700 Series retains these famous F & P features:

1. Predictable calibration performance
2. Stainless steel enclosures with safety vents
3. 360° rotatable end fittings
4. Safety glass windows
5. Immediate shipment from stock

And here's good news for large users of flowmeters. You can save 50 to 75% on inventory. Meter bodies and tubes can be stocked independently . . . ready to be snapped together and installed at a moment's notice. You stock only *three* body sizes to cover the entire flow range from a fraction of a cc/min to 40 gpm.

Prove to yourself how the simplicity of the 2700 Series Flowrator Meter can bring big savings to your plant. Call your local F & P Field Engineer or write for literature. Fischer & Porter Company, 400 County Line Road, Hatboro, Pa. In Canada, Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto, Ontario.

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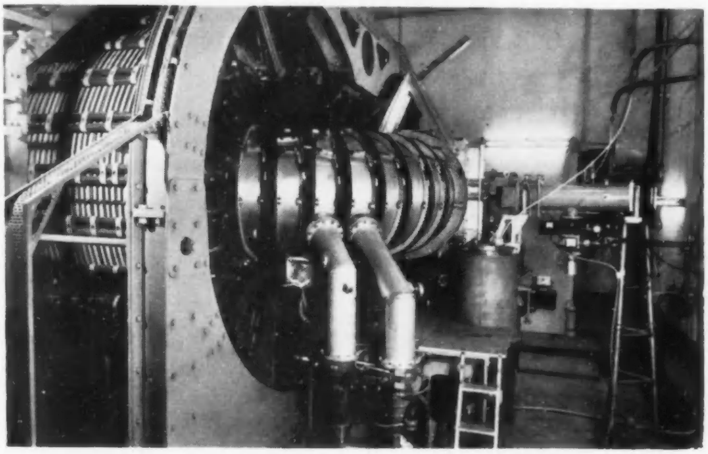

ZETA Sets the Pace In Fusion Studies

European editors report on the weird instrumentation used to reproduce thermonuclear reactions. Temperature is the big factor. Currently hitting 5 million deg C, Britain shoots for 25 to 50 million deg C in two or three months; but it's still a long way from the estimated 100 million to 1 billion required to sustain fusion.

In Harwell in January, U.S. and Britain opened the secrecy door a crack on fusion power research, allowed the world to see a collection of machines capable of reproducing thermonuclear reactions in the laboratory. The devices (whose names are almost as weird as the machines):

ZETA (Zero Energy Thermonuclear Apparatus)—Developed at Harwell, it is a donut-shaped gas discharge apparatus that stands 20 ft high; it has reached temperatures of over 5 million deg C.

Sceptre III—Another British machine with a toroidal discharge tube, has reached temperatures of 4 million deg C. This device is an industry project of British Associated Electrical Industries.

Columbus II—U.S. designed machine, uses a straight tube to initiate fusion reaction. Temperatures of up to 5 million deg C reached.

Columbus S-4—A later modification of the Columbus II with a longer, but still straight, tube.

Perhapsatron—U.S. device with a donut shaped tube, much smaller than ZETA, has reached temperatures of 6 million deg C.

All these machines are devices to create a gas discharge; all have been designed to attempt to reproduce hydrogen fusion—the process that generates energy in the sun—in the laboratory. It's been known since the early 1930's that if four nuclei of hydrogen were fused into a single helium nucleus, the resulting difference in mass would be made up by the emission of large quantities of energy. In the sun, using light hydrogen, it takes millions of years to complete a fusion cycle. That's why researchers are trying to fuse two nuclei of deuterium or one nucleus of deuterium with one nucleus of tritium. Such reactions occur quickly under the proper conditions.

These conditions include tremenously high temperatures, which explains the emphasis on reaching temperatures in the multi-million-degree range. To do this, all the machines change the ingredient deuterium gases into a plasma—a wholly ionized gas—then pass a tremendous surge of electrical current through them.

The surge has two effects. First it heats the gas to high temperatures. Then it gives rise to the "pinch effect", which makes the machines "magnetic bottles", keeping the high-

. . . Zeta's sustained the fusion reaction for only 5 millisec . . . temperature plasma from touching the sides of the gas-discharge tube. Here's how it works. Movement of the plasma sets up a magnetic force around the plasma (just like the current in a copper wire sets up a magnetic field around it). The magnetic forces act to contain the plasma in a thin line, pinch it into the center of the tube.

Unfortunately, plasma is highly unstable. It tends to break up, and some of the ions move randomly to strike the side of the tube. Britain's major contributions in the new machines are two techniques to sustain the life of the pinched plasma. British scientists use the eddy currents that move around a metallic gas discharge tube in which the reaction takes place, to help stabilize the plasma. They also try for stability by sending a small current around the outside of the discharge tube.

• **Details of ZETA**—Biggest of these plasma machines is ZETA, the result of five years' work at Harwell. Its heart is a ring-shaped aluminum tube, filled with deuterium at pressures of 10^{-4} mm hg. In operation, the gas is weakly ionized by a 3-kilowatt, 3-mc. rf source. Then the pulse energy, stored in 52 31-mfd condensors, is delivered. (Charging current of the condensers is limited to 4 amp by a saturated triode that brings the condensor voltage up to 25 kv within 9 sec.) Every 10 sec a mechanical switch discharges the 500,000 joules stored in the bank, sending it through a saturable reactor to limit the current build up in the switch.

The toroidal ionized gas plasma acts as a short-circuited secondary turn on the transformer. The pulse produces currents up to 200,000 amp in the gas. It's this amperage that causes the heating of the plasma.

Right now ZETA operates with a pulse period of 5 millisec with the periods between pulses running 10 sec. That means that thermonuclear reaction has been maintained for only 0.005 sec. To sustain the fusion reaction continually, the scientists estimate they'll need a temperature of between 100 million and 1 billion deg C.

• **Proof it's fusion**—There still is some doubt as to whether there's been real fusion produced. Sir John Cockroft, Harwell's director, maintained he was "90 percent certain" Britain's scientists are working with the condi-

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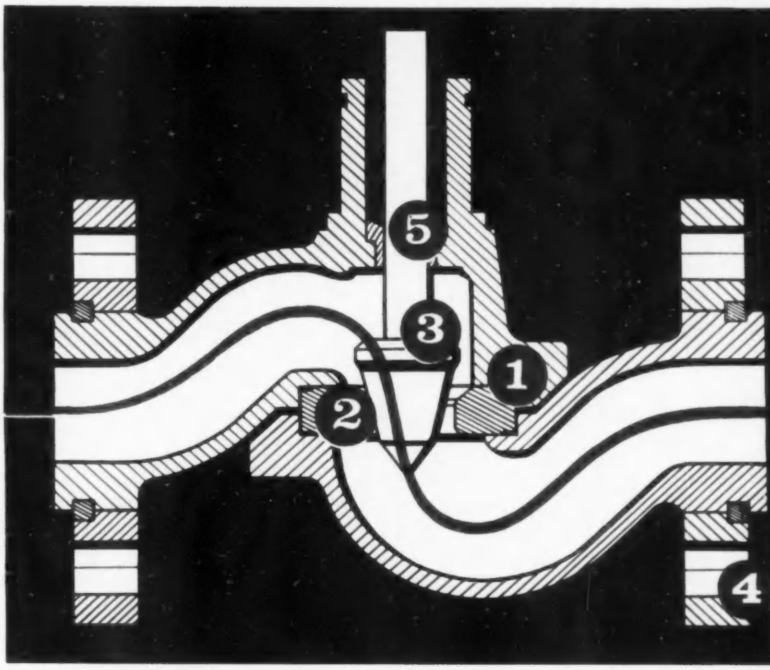

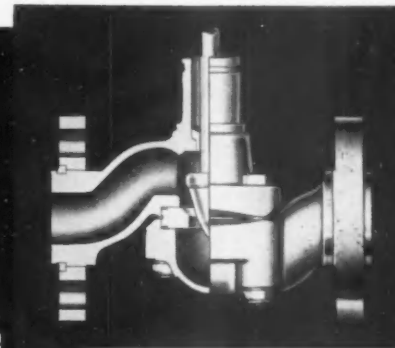

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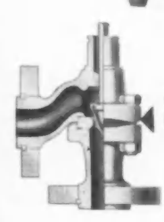
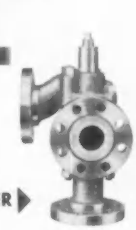


◀ ANGLE BODY



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◀ 3-WAY VALVE-GLOBE ADAPTER

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Control VALVES

tions needed for thermonuclear fusion and that ZETA demonstrated it.

The dispute centers around the neutrons emitted in the process. According to equations of nuclear physics, when the two nuclei of deuterium fuse, not only is helium and energy released but one neutron is also emitted. But the acceleration process caused by the high transient voltages which develop in gas discharges also produce neutrons—so-called cold neutrons. The big question: are the neutrons detected in ZETA and similar machines "cold" neutrons or are they particles produced by nuclear fusion?

• **Measuring temperatures**—One interesting problem that has been solved is measuring these multi-million-degree temperatures. Harwell is using seven techniques; of these, spectroscopy and Langmuir probes measure temperature directly.

In the spectroscopy method, the scientists use the doppler broadening of spark lines from minute quantities of oxygen and nitrogen introduced into the tube. This method supplies a direct temperature measurement accurate to within 20 percent. Measured on a quartz spectrograph, the breadth of the lines is approximately 1 angstrom. With more efficient burning of the deuterium, however, this technique may not be usable.

Langmuir double probes supply direct measurements of temperatures by gaging conductivity of the gas discharge. Still a third direct check is provided by radar pulses. The transmission characteristics of 4- or 8-mm radar pulses indicate temperature and electron density.

Indirect measurements are obtained from the neutron count using scintillation and BF_3 counters. However this data is controversial since not all the neutrons are the result of fusion.

• **Controls on a fusion plant**—Looking a step ahead—at least 20 years, by most prognostications—thermonuclear power generation will require relatively simple controls. Basically, the whole system is static with pulse techniques providing input power and transformers coupling-setting the output distribution. The energy gain in the torus—the heart of the generation system—is itself controlled primarily by the energy input levels and torus dimensions.

That leaves little to control. The main requirements will be monitoring. The prime variable: gas temperatures.

—John Tunstall, Derek Barlow

WHAT'S NEW

Conclaves Ahead

March and April loom as busy months for control engineers, with several technical meetings of special interest.

IRE, MARCH 24-27

The 1958 National Convention of IRE will open in its traditional New York City setting on March 24, feature 55 sessions at which 280 papers will be presented. The concurrent Radio Engineering Show will house 850 booths exhibiting an estimated 20,000 products. Technical sessions of special interest to control engineers:

Session 3—Telemetry & Remote Control
Monday, March 24, 2:30-5:00 pm; Jade Room, Waldorf-Astoria

Session 9—Automatic Control
Tuesday, March 25, 10:00 am to 12:30 pm; Starlight Roof, Waldorf-Astoria

Session 25—Electronic Systems in Industry
Tuesday, March 25, 8:00-10:30 pm; Faraday Hall, Coliseum

Session 37—Electronic Systems in Industry
Wednesday, March 26, 2:30-5:00 pm; Sert Room, Waldorf-Astoria

Session 44—Industrial Electronics
Thursday, March 27, 10:00 am-12:30 pm; Sert Room, Waldorf-Astoria

Session 46—Data Reduction & Recording
Thursday, March 27, 10:00 am-12:30 pm; Morse Hall, Coliseum

In Tuesday's automatic control session, to be chairmanned by Magnavox's John M. Salzer, these three papers stand out: "On the Design of Adaptive Systems" by H. L. Groginsky, Columbia University; "The Organization of Digital Computers for Process Control" by G. Post and E. L. Braun, Litton Industries; and "A Self-Adjusting System for Optimum Dynamic Performance" by G. W. Anderson, J. A. Aseltine, A. R. Mancini, and C. W. Sarture, Aeroneutronic Systems, Inc.

NEW JERSEY, ISA, APRIL 1

The annual symposium sponsored by the New Jersey Section, ISA, has slowly but surely been growing into a meeting of national stature. This year, the year of the 10th symposium, that national stature is strongly reflected in a slate of technical papers from all over the U.S. that will bring

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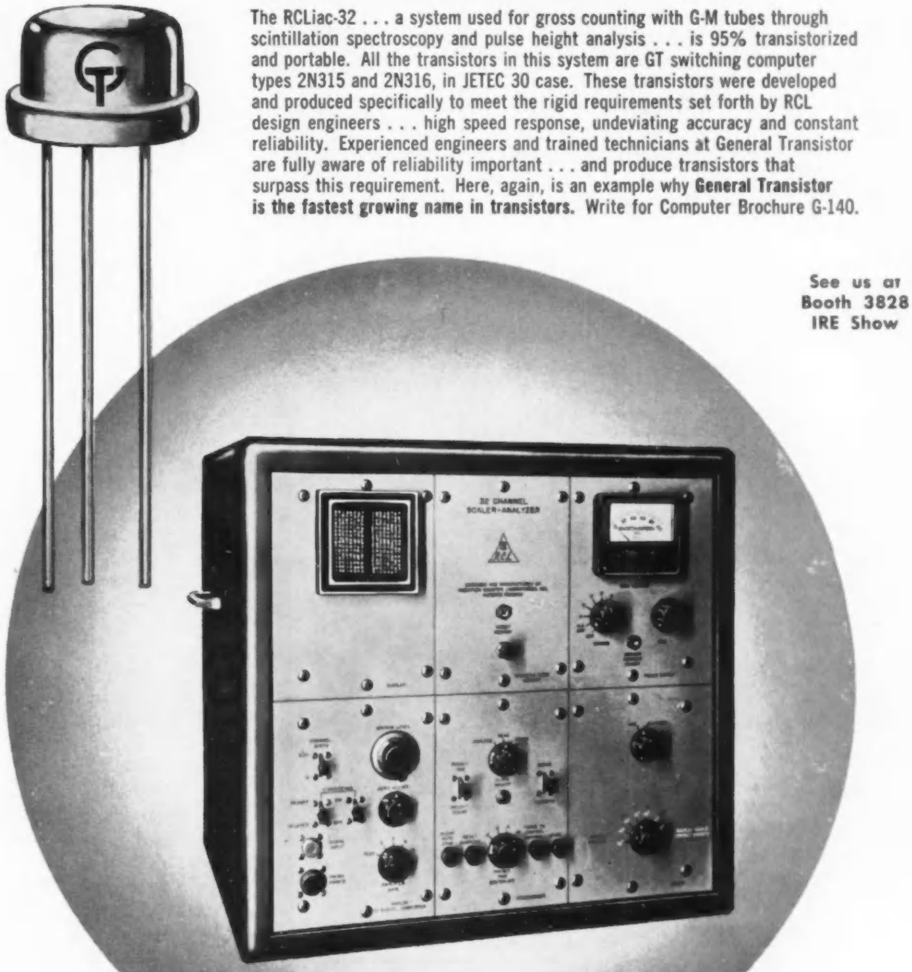

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the subject of control systems engineering to the local level in the process industries.

N. B. Nichols, Taylor Instrument Cos., will moderate the program, which will include these papers:

- "The Control Loop" by Bruce E. Powell, California Research Corp.
- "Analyzing the Control Loop" by Geraldine A. Coon, Taylor Instrument Cos.
- "Testing the Process in the Field" by David W. St. Clair, du Pont.
- "Simulating the Process and Controller with an Analog Computer" by Roger G. E. Franks, du Pont.
- "The Systems Approach to Control Problems" by C. D. Close, CDC Control Services, Inc.

In an evening session, a panel will tackle the subject of "Implementing Control Systems Engineering", concentrating on an attempt to pinpoint the time when the process engineer should get instrument engineering in the systems approach. The meeting will be held at the Essex House in Newark.

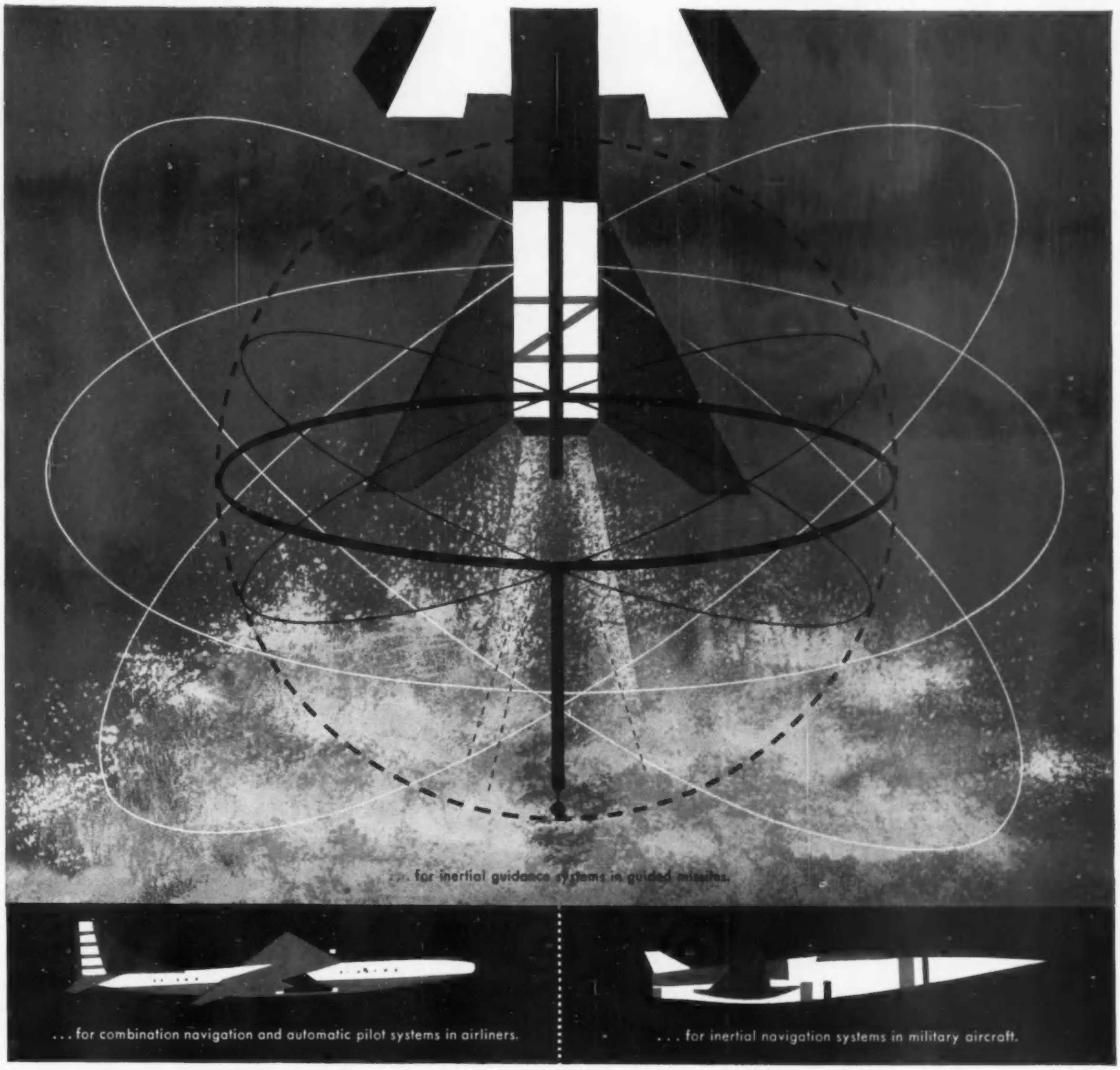
ASME/IRD, APRIL 2-4

Automatic Optimization will be the theme of the fourth annual conference of the Instruments & Regulators Div., ASME. Meeting at the University of Delaware, the conference will incorporate participation by professional groups from the AIEE, IRE, ISA, and AiChE. Four technical sessions and a panel discussion make up the heart of the meeting.

The papers scheduled to be presented include both theoretical and practical slants. Typical examples:

- "An Approach to Self-Adaptive Controls" by C. F. Taylor, Daystrom Systems Div.
- "Methods for the Realization of Self-Optimizing Systems" by M. J. Levin, Columbia University.
- "Continuous Measurement of System Characteristics" by T. P. Goodman and R. H. Hillsley, MIT.
- "A Technique for Optimizing Process Conditions" by A. L. Hoerl, du Pont.
- "Dynamic Analysis of a Boiler" by K. L. Chien, E. I. Ergin, C. Long, Beckman Systems, and Allyn Lee, U.S. Navy Bureau of Ships.
- "A Gyro-Integrating Mass Flowmeter" by L. T. Akeley, L. A. Btacelder, D. S. Cleveland, General Electric Co.

Registration at least two weeks in advance is suggested by the meeting committee, to guarantee sufficient accommodations at the university.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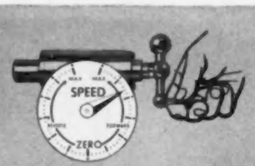


AROUND THE BUSINESS LOOP

IBM Clears Its T-Zone

More emphasis on R&D seen in deal to buy Texas Instruments' transistors; a word or two on PR procedures.

Not as a rule a self-effacing company, IBM could tell a reporter in New York City barely a thing about its new agreement with Texas Instruments, Inc., involving purchase of TI transistors. But when it was pointed out to some IBM data-processing people at White Plains, N. Y., that their company's silence kept the doors locked on the answers to several questions provoked by the agreement, they offered a precedent-setting piece of news: virtually all IBM transistor production facilities will soon be turned over to limited amounts of newly developed or special-purpose designs, a clear indication that all future supplies of transistors for ordinary use would come from outside sources.

A week after the agreement was arranged in Dallas, the home of Texas Instruments, information about it had reached IBM personnel in New York in a spotty fashion only. At one point, part of the TI release had to be read over the telephone to a member of the IBM staff in New York City world headquarters, where copies were scarce. At White Plains, personnel were told to say that more information on the IBM-TI deal could be obtained by contacting Patrick Hagerty, a TI vice-president. No reason was given for IBM's decision to let TI carry the ball on the publicity. And the only thing readily acknowledged was that the blackout on IBM's part had been deliberate. Why, could not be said.

• **Immediate purchase**—According to Texas Instruments, the agreement establishes a means by which the two companies "will work together in the area of transistors for data processing machines". Slated for immediate implementation are an exchange of technical information, with the proper mutual safeguards, and IBM purchases of "a substantial portion of its expanding future commercial transistor needs" from TI.

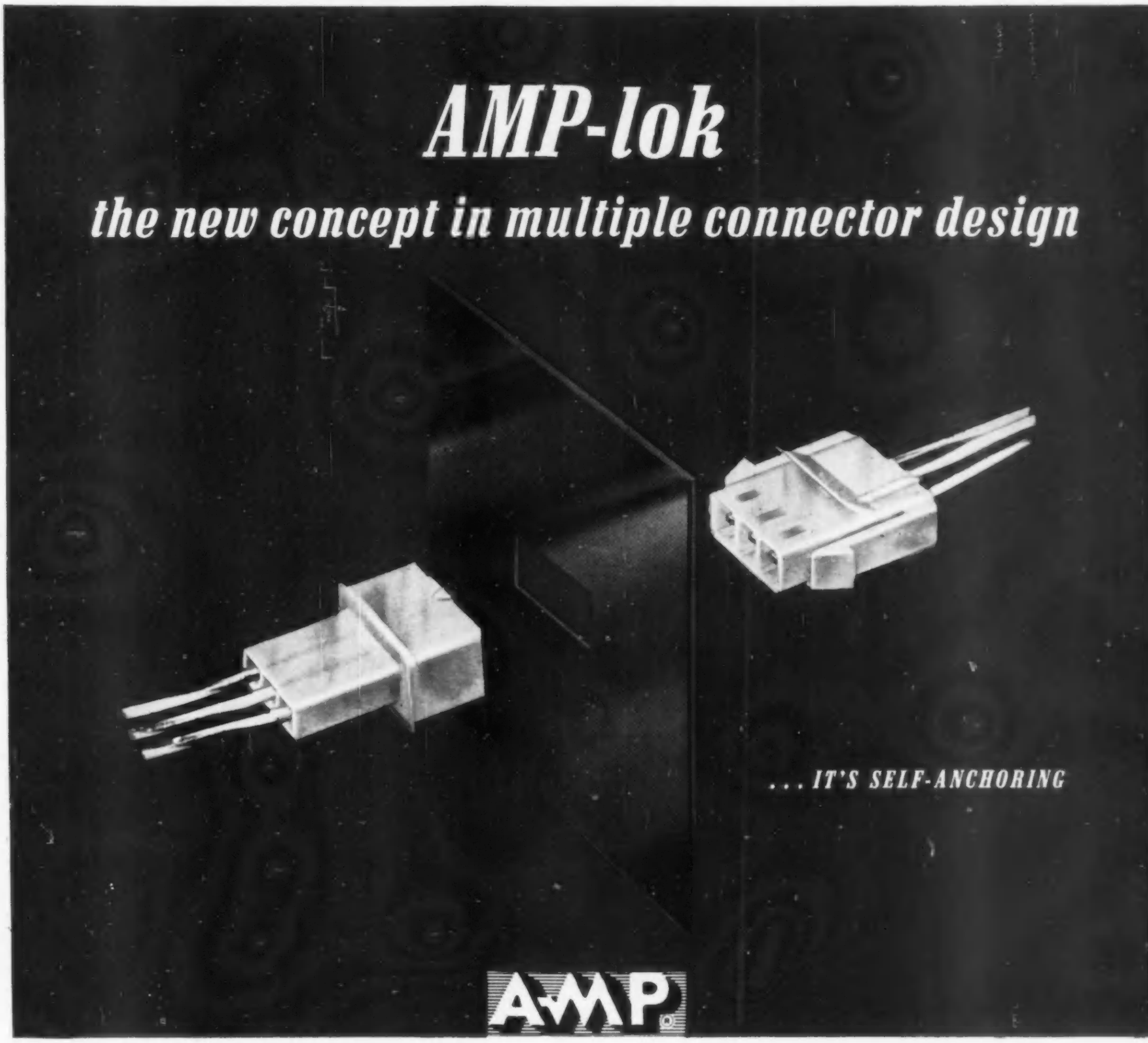
The fact that it was said that no restrictions would be placed on either company's present or future relations with other customers and suppliers gave the agreement a long-range look; but this, said an "industry source" quoted by the weekly *Electronic News*, was not so. It was his understanding, said this source, that there was a definite time limitation. *EN* also indicated that IBM could be using the agreement to clear the decks for manufacture of other types of switching devices, notably cryotrons, the new bi-metallic elements that can exist only in near-zero temperatures.

• **All set financially**—One thing was certain, at any rate, and that was that no two companies are in better positions financially to go into new ventures than IBM and Texas Instruments. In a report on its preliminary results for 1957, IBM noted that its gross volume of business soared over $1 billion for the first time in its history (gross income: $1,000,431,597). In 1956 this figure was a mere $734,399,780. The business-machine maker also observed that its net income for the year just passed amounted to $89,291,589, compared to $68,784,510, and that the former figure included $3,927,000 from the outright sales of punched-card accounting and data-processing machines (CtE, March '56, p. 30).

For its part, TI expects net sales for 1957 to exceed $65 million, which would be a 45-percent increase over the $45.7 million recorded the year before, and would represent, among other things, record sales of transistors and related semiconductor devices. In its year-end report, TI also pointed to its putting into commercial production new gaseous diffused-junction silicon transistors for the missile program. All these developments were undoubtedly factors in the agreement with IBM.

New Divisions and Groups

A test instrumentation laboratory for infrared instruments, established in Riverside, Calif., by **IR Industries, Inc.** Manager is Arthur J. Cussen, formerly head of the Infrared Div. of the Naval Ordnance Laboratory, Corona, Calif., and a top authority on infrared detector performance. Under Cussen, who is also managing editor of the quarterly "Proceedings of Infrared Information Symposium", the laboratory will design, develop, and



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manufacture test instrumentation for IR measurements, and serve as an infrared test and evaluation center for industry and the government.

A Systems Group in **Varian Associates**, headed by William J. McBride Jr., the former manager of the company's Klystron Development Dept. The new separate operating unit, combining the former Systems Development and Linear Accelerator Groups, will handle new products that do not fit into standard product lines of the Tube and Instrument divisions. The field of linear accelerators is a brand new one for Varian, but already three orders have been received for the complex machines. McBride's area is prototypes of advanced microwave instrumentation systems.

A Manhattan (N. Y.) Computer Center, expected to go on a 24-hour duty solving problems on analog computers for customers of the parent **Mid-Century Instrumatic Corp.** In charge of the $250,000 center will be personnel of Mid-Century's Computing Services Div. Charter subscribers will be charged a nominal $28.50 an hour for the use of 48 of the available 136 amplifiers. Practically every area involving control will be served.

An Instrument Div., formed to manufacture and market **Schutte & Koerting's** line of precision devices for measuring fluid rate of flow. To the division go a brand new research and test center in Bucks County, Pa., and the following executives, among others: Ralph W. Eberly, formerly manager of meter sales and engineering, manager, and Walter F. Dydak and Paul R. Kasmer, supervisor of sales and design engineering.

United Testing Laboratories, a new Monterey (Calif.) unit of **United ElectroDynamics** of Pasadena, which in turn is an outgrowth of United Geophysical Corp. The new facility includes the only commercial laboratory on the coast that can handle major fuse-testing assignments; it also has accommodations for testing a complete inertial guidance system and labs devoted to standards, electronic components and systems, instrumentation, and electromechanics. R. D. Fagaly is general manager.

An "office automation" R&D center formed by **The National Cash Register Co.** "to help dig American business out from under its mountain of paperwork". Nearly 1,000 researchers and engineers work in a 250,000-sq-ft are enclosing a computer, weather- and sound-proof laboratories, and other impressive facilities.

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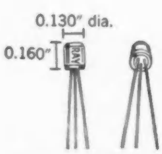

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COMPUTER TRANSISTORS
Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	f_{ab} ave. Mc	H_{FE_1} ave. $I_B = 1$ ma $V_{CE} = -0.25V$	H_{FE_2} ave. $I_B = 10$ ma $V_{CE} = -0.35V$	Rise Time* max. µsec
CK25	2N425	−20	4	30	18	1.0
CK26	2N426	−18	6	40	24	0.55
CK27	2N427	−15	11	55	30	0.44
CK28	2N428	−12	17	80	40	0.33

*I_C — 50 ma; I_{B_1} = 5 ma; R_L = 200 Ω; I_{B_2} = 5 ma; Grounded Emitter Circuit

GENERAL PURPOSE AUDIO TRANSISTORS
Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	Beta ave. small signal	Power Gain Class A ave. db	I_{co} ave. µa	Noise Factor ave. db
CK22	2N422	−20	90	40	6	6 max.
CK64	2N464	−40	22	40	6	12
CK65	2N465	−30	45	42	6	12
CK66	2N466	−20	90	44	6	12
CK67	2N467	−15	180	45	6	12

GENERAL PURPOSE RADIO FREQUENCY TRANSISTORS
Temperature Range −65°C to +85°C

SUBMIN Type	JETEC-30 Electrical Equivalent	V_{CE} max. volts	f_{ab} ave. Mc	Beta ave.	C_{ob} ave. µµf	r_b' ave. ohms
CK13	2N413	−18	2.5	25	12	70
CK14	2N414	−15	6	40	12	80
CK16	2N416	−12	10	60	12	90
CK17	2N417	−10	20	80	12	100

Dissipation Coefficients for all submin types: in air, 0.75°C/mW; infinite sink, 0.35°C/mW

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Mergers Make Big News

Marriage of Norden-Ketay and Solar Aircraft in U. S., and that of Elliott Bros. and Associated Automation in England are both significant, though circumstances differ.

The same day it traded 38,700 shares to make it the most active stock on the American Stock Exchange, Norden-Ketay Corp. announced a director-approved merger with Solar Aircraft Co. A week before, N-K had led *The New York Times*' "most active list" with 88,400 shares traded. But most of this activity had, unfortunately, been downhill, creating a need, in the words of Chairman Paul Adams, for "substantial additional capital funds in order to preserve our status and maintain the potential of our company".

The merger agreement calls for an exchange of all of the 1,293,193 shares of Norden-Ketay's common stock outstanding for about 230,000 shares of Solar's 700,052 common outstanding. This is a ratio of one share of Solar for every 5.62 shares of Norden-Ketay. Said Adams to his stockholders: "Your company was hit hard by government contract rescheduling and the receipt of virtually no new production business, while the defense effort was being appraised." As a result, he said, there was a "serious reduction of working capital".

In 1956 Norden-Ketay's sales amounted to $22,752,993, up 68 percent from the year before (CtE, May '57, p. 52). In the subsequent 11 months, this figure went even higher, to $25,213,724. But in both periods net loss also increased: in 1956 to $505,280, and in 1957 to $1,107,667. Solar's sales for the year ended April 30, 1957, were $83,118,545, up from $51,645,522 (CtE, Dec. '57, p. 54). Its net income was down for this period, but there had been manufacturing problems and a strike.

* * *

Since the war Elliott Bros. of London has been steadily negotiating its way to a top position among the control and automation groups in Europe. Up to 1955, activities of the 158-year-old company were primarily in process control, aviation, and instrumentation. Then came an expansion of interests that placed it squarely in fields ranging from hydraulic conveyors to food-preparation machinery. Just as 1957 came to an end, Elliott began discus-

two more UNIT PREAMPLIFIERS

in the new

SANBORN "450" SERIES

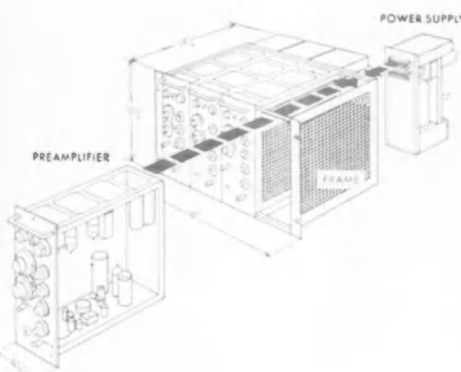
Here are the newest of the recently introduced Sanborn "450" Series Unit Preamplifiers—compact, lightweight, self-contained instruments for use with optical and tape recorders, wide band 'scopes, panel meters, computers, etc. (For use with high speed optical galvanometers at frequencies above 500 cps, requiring larger current swings, a transistor output amplifier is built into the 450-1800A True Differential DC type and available as optional equipment on other 450's.) As with all 450 Unit Preamplifiers, the new Servo Monitor and DC Coupling models mount in either individual portable cases or in the four-unit 19" module frame (#354-1100-C2) shown. The *450* designation refers to *unit packaging* of Sanborn 350 Preamplifiers and Power Supplies in individual 450 cases. Loosening two front panel thumbscrews allows quick, simple interchangeability. Since *all* "450" Preamps use the 350-500 Power Supply (which remains in place at the rear of the frame or case), new requirements necessitate only additional *Preamplifier* units, permitting sizable savings in equipment investment.

The Model 450-1200 is a phase-sensitive demodulator, whose DC output voltage is proportional to the in-phase (or 180° out-of-phase) component of an AC signal with respect to a reference. Precision measurement is realized by such characteristics as negligible quadrature signal error, provision for floating signal and reference inputs, front panel VTVM for accurate calibration signals. The 450-1200 accepts the outputs of resolvers, synchros, differential transformers and other transducers. The 450-1300A is a moderate gain, balanced input—balanced output DC amplifier. Its input circuit performs equally well with single-ended or balanced signals.

The "450" Series Unit Preamplifiers presently include the Model 450-1100 Carrier, 450-1200 Servo Monitor, 450-1300A DC Coupling and 450-1800A True Differential DC types. Following these will be "450" Series Logarithmic and Low Level types. Further data and application information on present models is available on request.

Model 450-1200 Servo Monitor (Demodulator) Preamplifier

Model 450-1300A DC Coupling Preamplifier



MAJOR SPECIFICATIONS

MODEL 450-1200 SERVO MONITOR PREAMPLIFIER

Sensitivity: 5 mv (in phase) produces 1 volt at output jack under maximum output load conditions
Input Impedance: Signal 100k
Reference 12.5k for 15 volts, 55k for 120 volts
Frequency Response: 3db down at 20% of carrier frequency filter position
Carrier Frequency Filter: Selected by a switch (three positions)
Low 60 cycles
Med 400 cycles
Hi 1000 cycles (5000 cycles optional)
Reference Voltage: Internal selection accepts voltages from 15 to 120 volts
Quadrature Rejection: Ratio better than 100:1
Maximum permissible quadrature before overload indicator lights is twice full scale (in phase)
Calibrate Voltage: 10 millivolts internal (set by meter on panel)
Drift: Less than 0.1% of full scale per hour
Preamplifier Output Jack: ±3 volts available into 2.2k minimum load resistance. Output appears across two cathodes at approximately ground potential
Rear inputs and **overload indicator lights** are included
Output Impedance: 1k
Overall Linearity: ±¼%
Power Requirements: 115 volts, 50-400 cycles, approximately 35 watts

MODEL 450-1300A DC COUPLING PREAMPLIFIER

Sensitivity: 50 mv produces 1 volt at output jack under maximum output load conditions

Input Impedance: 5 megohms each input side to ground

Input: Single-ended or push-pull

Preamplifier Output Jack: ±3 volts into 2.2k minimum load resistance. Output is balanced and appears across 2 cathodes at approx. ground potential

Output Impedance: 1k

Drift: Referred to input 2 mv/hr. line voltages change less than 10%

Frequency Response: 0-20kc

Calibration: 100 millivolts internal

Linearity: ±¼%

Rear inputs included

See the new "450's" and other Sanborn equipment at Booth 3601-3603 I. R. E. Show

SANBORN COMPANY
INDUSTRIAL DIVISION
175 WYMAN STREET, WALTHAM 54, MASS.

WHAT'S NEW

sions with Associated Automation, Inc., also of London, about a possible merger. That merger, now completed, has brought about what is probably the largest automation and instrumentation organization in Europe.

Associated Automation was formed in 1928 as the Hall Telephone Co., a manufacturer of telephone ancillary equipment. It changed its name in 1955 and was joined by James Gordon & Co., Inc., combustion control specialists; in 1956 Electroflo Meters Co., Ltd., one of the largest producers of flow meters and controllers in the United Kingdom, came in. Licensing agreements with Panellit added data-reduction and logging equipment, and agreements with Sauter Controls, Ltd., added air conditioning and heating controls.

• **Diversified**—Under the Elliott banner in the U.K. are these subsidiaries: Bristol Instrument Co., Ltd., Fisher Governor Co., Ltd., Rotameter Mfg. Co., Ltd., B&P Swift, Ltd., Swift & Swallow, Ltd. (food preparation), and Webb Conveyors & Automation, Ltd. On its own, Elliott is carrying on guided missile, nuclear-control, and, especially, computer development work. Under a long-term agreement, its 402 business computers are marketed through the U.K. and Europe by The National Cash Register Co. In addition, it owns a major share of Associated Insulation Products, Ltd., a holding company that operates several subsidiaries in the insulation field.

A rundown of the divisions of the new $30 million Elliott-Automation Group shows activity in just about every field of control and automatic-system development. This means process control, switchboard instrumentation, electronic computing and control, electronic industrial weighing, fire control, guided missiles, microwave work, and nucleonics. Its interconnection with other control firms is international, with licensing agreements with Bendix Aviation Corp., G. M. Giannini & Co., Inc., Industrial Instrument Corp., The Swartwout Co., as well as the American counterparts of some of Elliott's subsidiaries.

Production by the group's divisions is spread through nine plants, of which six are in the London area. A payroll of nearly 8,000 saw to it that the group made a pretax profit in 1956 of a healthy $2.7 million.

* * *

Consolidated Electrodynamics Corp. and Cenco Instruments Corp. (for-

merly Cenco Corp.) have announced they are negotiating to combine. A marriage of the big California controls manufacturer and the 75-year-old Chicago laboratory-instrument maker would create a selling power of at least $44.5 million a year—$30 million on CEC's part and $14.5 on Cenco's (1957 figures). It would unite CEC facilities in California and New York, and Cenco operations in California, Chicago, Tulsa, and Canada.

Said CEC's Chairman Philip S. Fogg, "Cenco's nationwide organization for the marketing of laboratory equipment and scientific instruments will open new avenues for the exploitation of many CEC products. At the same time, Consolidated's broad research and development program should add significant new products to Cenco's well-established line." Cenco's President Alfred A. Strelsin indicated that the merger "should result in one of the country's outstanding instrument organizations". Tentative agreement calls for an exchange of three shares of Cenco stock for every CEC share.

New Companies in the Field

Metrix Corp., organized by a group of former Baldwin-Lima-Hamilton senior engineers to champion the strain gage—in Newton, Mass. The men are: Malcolm Green, who will be in charge of manufacturing; David J. First, who will oversee engineering, and Stanley Charren, whose area will be sales. All three were associated with B-L-H's Electronics & Instrumentation Div. The new company will manufacture instrumentation for use with strain gages and strain-gage devices, and will fabricate systems based on them. Its first product will be a test bridge for very accurate millivolt-per-volt signals for instrumentation checkouts. Green, the former assistant chief engineer of the B-L-H division, was with Ruge deForest, Inc., when it was bought by B-L-H in 1955.

Watkins-Johnson Co., which will specialize in microwave tubes under the guidance of a Stanford professor of electrical engineering and a former Hughes Research Laboratories engineer-executive—in Palo Alto, Calif. Dean A. Watkins, who will continue in his position at Stanford, is president of the new concern, and H. Richard Johnson, who headed the Microwave Tube Dept. of the Hughes laboratories, is vice-president.

[Continued on page 160]

HERE'S ONE — MORE TO COME

New Skinner Valves at Low Prices

2-way normally closed shown actual size.

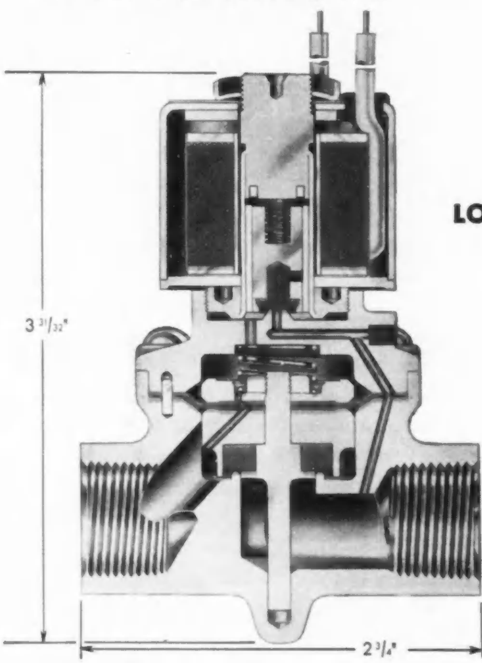
Here it is — one of the many new lines Skinner will bring you in 1958. A new 2-way, normally closed, pilot-operated valve that is lighter in weight — only 1 ¾ pounds — and smaller in size, yet permits full flow through a ½" orifice with ⅜" or ½" pipe taps.

The valve handles pressures from 5 psi to 150 psi, with temperature ranges from —40°F to 180°F, and will operate on all popular AC and DC voltages. It's small but rugged, economical but efficient — manufactured to the highest engineering standards of the Skinner Valve line.

Versatility is also a feature of the new Skinner® L Series; modifications are already available for normally open operation, with such options as manual override, explosionproof construction and choice of electrical connections to fit your application requirements.

• • •

You can get full details of this exciting, new valve line by writing us direct or by contacting the Skinner Representative or Distributor near you. He's listed in the Yellow Pages. Write Dept. 343.



LOOK AT THESE HIGH-QUALITY FEATURES:

- Unique Diaphragm Design — by actual test, this new design outperforms all others — the diaphragm is completely supported at all times. The nylon-reinforced buna diaphragm has a high resistance to media impurities, and only a small area is exposed to pressure, which assures long, trouble-free life.
- So Easy to Mount — so light in weight that it can economically mount directly to line.
- Operates upside down, sideways, in any position — strong spring action snaps valve shut — every time.
- Forged Brass Body — provides low porosity and dense metal structure for rugged application and no leakage.
- Low Wattage Consumption — coil consumes only 8 watts, considerably less than comparable valves.
- Soft, Synthetic Inserts — withstand constant opening and closing of pilot and main orifices — are long-wearing and provide absolute bubbletight operation.
- Internal Stainless Steel Parts — eliminate internal rusting, clogging or contamination.

SKINNER ELECTRIC VALVES

THE CREST OF QUALITY

SKINNER ELECTRIC VALVE DIVISION NEW BRITAIN CONNECTICUT 105 EDGEWOOD AVENUE

STATISTICAL COMMUNICATION TECHNIQUES and SPACE TECHNOLOGY

The transmission of information to the earth from a ballistic missile or a space vehicle presents unusual problems in communications. With severe limitations on equipment size and power, the communication system must operate in the presence of receiver noise and interference from the radio environment, including terrestrial sources and, for longer ranges, sources in space. Statistical communication techniques are valuable tools in achieving reliable communications under these difficult conditions. These techniques, by providing means for coding and decoding information and for determining the amount of information which can be sent, make possible the use of low-strength signals which otherwise could not be sorted out from the background of interference and noise.

The statistical approach is also important in the development of systems with a high degree of immunity to electronic countermeasures. The less regular or predictable the nature of transmitted waveforms, the less likelihood there is that interference will prove effective against the communication system. However, it is necessary to design the system to take maximum advantage of the near-random waveform characteristics.

Future space vehicles inherently will impose greater demands on communication systems. Systems for guidance, tracking, and data transmission through space to the moon or the nearer planets are now real goals in space technology. In the development of such systems, statistical communication techniques can be expected to play a significant role.

At Space Technology Laboratories, both experimental and analytical work are proceeding in the application of statistical techniques to the problems of space vehicle electronics. This work illustrates the advanced research and development activities in STL's Electronics Laboratory and the emphasis upon the application of new techniques to the requirements of space technology.

Both in support of its over-all systems engineering responsibility for the Air Force Ballistic Missile programs, and in anticipation of future system requirements, STL is engaged in a wide variety of research and experimental effort. Projects are in progress in aerodynamics, propulsion, structures, and electronics.

The scope of activity at Space Technology Laboratories requires a staff of unusual technical breadth and competence. Inquiries regarding the many opportunities on the Technical Staff are invited.

SPACE TECHNOLOGY LABORATORIES

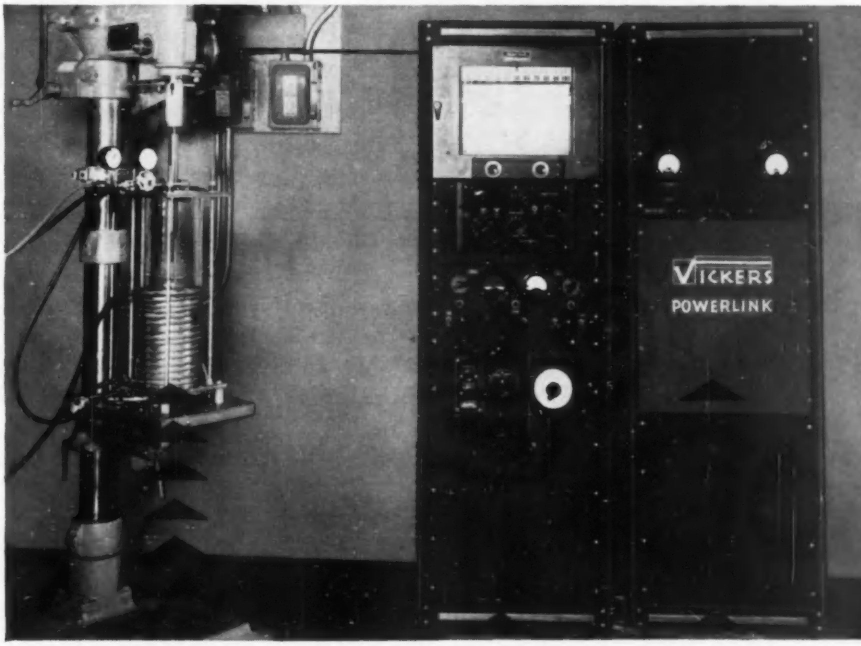
A Division of The Ramo-Wooldridge Corporation

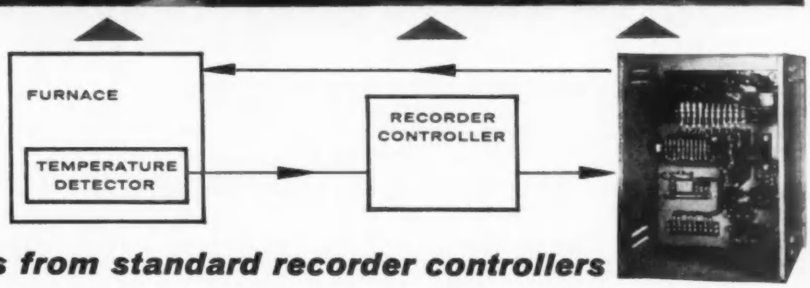
5730 ARBOR VITAE STREET • LOS ANGELES 45, CALIFORNIA

for precise automatic furnace temperature control

THE NEW VICKERS® MAGNETIC AMPLIFIER

POWERLINK





POWERLINK

uses signals from standard recorder controllers

Where kilowatts of power must be precisely controlled by milliwatt signals, the Vickers Powerlink offers:

- **Fast speed of response.**
- **Proportional stepless control, providing greater precision.**
- **Freedom from maintenance, in contrast to off-on contactor method of control.**
- **Easy installation, with no contractor required. Only a disconnect switch is needed.**

A Powerlink serves in the electric furnace shown above, in which silicon crystals are grown—a process demanding extremely accurate temperature maintenance. The furnace, controlled by a Powerlink unit used in conjunction with a recorder controller, is held at 1500° C., with temperature variation of only ±0.4° C.

If your operation requires precise control of high power with low level signals, the Vickers Powerlink unit is tailor-made to fit your needs. It is available in 11 standard sizes ranging from 1.5 to 10.0 kilowatts, with input resistance of 2000-20,000 ohms, and milliampere input ranges of 0-5 m-a, 0-15 m-a, 4-8 m-a and 0-20 m-a. Units are completely wired ready for immediate installation.

Write today for complete information on the Vickers Powerlink.

ELECTRIC PRODUCTS DIVISION VICKERS

VICKERS INCORPORATED

DIVISION OF SPERRY RAND CORPORATION

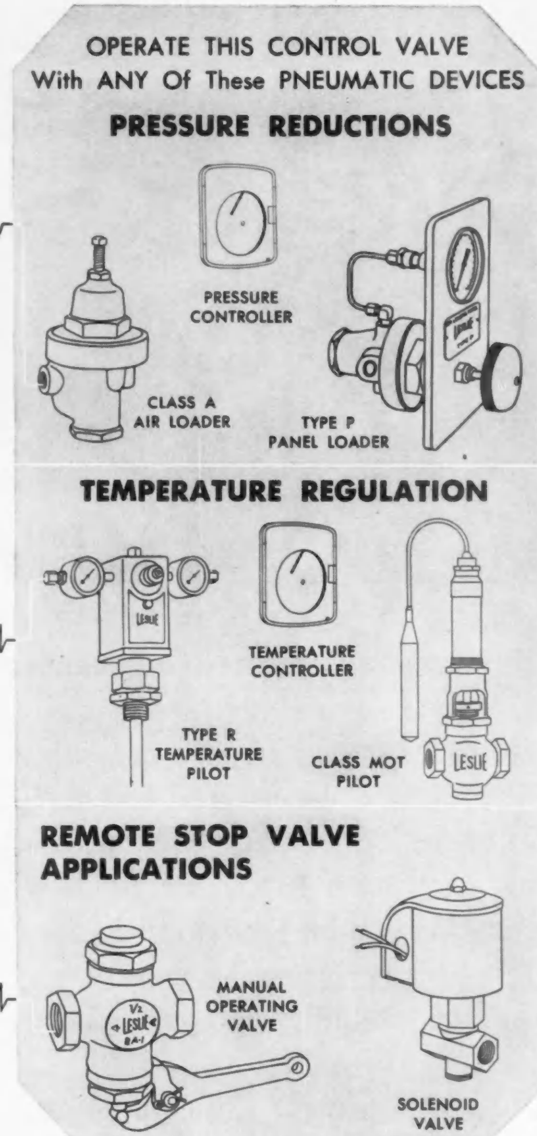
ELECTRIC PRODUCTS DIVISION

1805 LOCUST STREET • SAINT LOUIS 3, MISSOURI

A NEW

LESLIE

FINAL CONTROL ELEMENT



A REALLY VERSATILE *packless!** CONTROL VALVE — with only two moving parts *and a metal diaphragm**

Now, simplified instrumentation combines the simple air loaded, Leslie diaphragm operated valve with various air operated devices. This is the valve that filled a real need when introduced about a year ago, wearing a 3-year guarantee against maintenance in normal pressure reducing services.

This new final control element is gaining wide acceptance for use with a variety of pneumatically operated controllers — simplifying pressure reductions, temperature regulation, remote stop valve applications and many process steam control services.

Ideal for "problem" installations

This control valve is ideal for either continuous or intermittent service and has remarkable immunity to dirty steam. Furnished in cast iron, sizes ½ - 2", it is suitable for any steam service up to 250 psi, 450F, and many fluid services.

It's simple — it's accurate

This Leslie control valve has only two moving parts ... no fussy seals, no stuffing boxes, no small dirt-catching parts; yet, with all its simplicity, it provides uncanny accuracy with its *double** feed-back action. It lends itself readily to remote adjustment, too.

More Information

Ask your Leslie engineer to tell you more about this really versatile valve and the simplified instrumentation "packages" now available. You'll find him listed in your classified directory under "Valves" or "Regulators" and eager to come up with new ideas for simplifying pressure, temperature and liquid level control systems.

Send for Bulletin 561-A

** These are the President's comments — even the ad manager didn't know all the fine features!*

LESLIE REGULATORS and CONTROLLERS

640 211 Grant Avenue, Lyndhurst, New Jersey

These could be the

MOST IMPORTANT RELAY "SPECS"

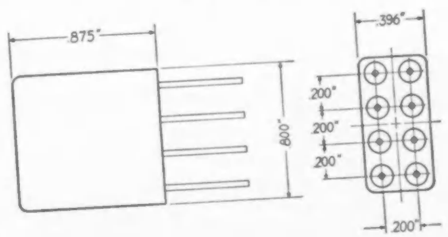
you ever read!

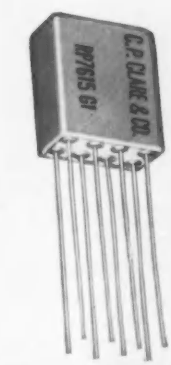
• Here is a relay admirably geared to the needs of today's advanced circuit designers. Hermetically sealed—no bigger than a postage stamp—stalwart to withstand extremes of temperature, heavy shock and severe vibration—yet fast and more than moderately sensitive.

CLARE *Type F* RELAY

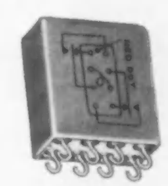
SPECIFICATIONS

Ambient Temperature	—65° C to +125° C.
Shock	50 Gs for 11 milliseconds.
Vibration	5-75 cps at maximum excursion of ⅛-inch, 75-2000 cps at 20 Gs acceleration.
Dielectric Strength	Sea level—1000 volts rms between terminals and frame, and between adjacent circuits; 750 volts rms between contacts of a set. At 80,000 ft., 350 volts rms.
Insulation Resistance	1000 megohms minimum at 125° C.
Coils	Coils up to 10,000 ohms available for a wide range of voltages or currents.
Nominal Operating Power	250 milliwatts.
Pickup Time	3.5 milliseconds nominal.
Dropout Time	1.5 milliseconds nominal.
Contact Arrangement	2 pdt (2 form C).
Contact Rating	3 amps resistive at 28 volts d-c or 115 volts a-c; also for low-level applications.
Contact Resistance	0.050 ohm maximum.
Contact Life	500,000 operations minimum at 2 amps; 100,000 operations minimum at 3 amps.
Enclosure	Hermetically sealed, filled with dry nitrogen at 1 atmosphere pressure.
Mounting	All popular mounting arrangements available.
Terminals	Printed circuit; solder; plug-in (matching socket available). Variations of printed-circuit terminal length on 1/10-inch grid spacing available.
Weight	17 grams.
Military Specifications	MIL-R-25018; MIL-R-5757C, except as to contact overload.

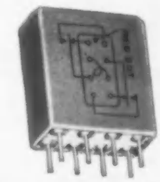




Designers of printed circuit layouts will note terminal arrangement is nicely suited to 1/10 inch grid spacing.



Contacts, rated at 3 amperes, are proven also for low-energy level circuit applications.



All popular mounting arrangements are available.

For complete information send for Bulletin 124. Address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 2700 Jane Street, Toronto 15. Cable Address: Clarelay

CLARE RELAYS

FIRST in the industrial field

MISSILE QUALITY AC DRIVE MOTORS

Oster®

Complete Line / *Gear Trains Available with Many Types*

Meet MIL-E-5272A / Dimensions from 15/16" to 2–3/8".

SIZE	VOLTAGE	FREQ. C.P.S.	NO. PHASES (SUPPLY)	NO LOAD SPEED (RPM)	CAPACITOR (MFD)	RUNNING CURRENT AMPERES	RUNNING WATTS INPUT	OUTPUT	WEIGHT	GEAR RATIO	TYPE NUMBER
10	115	400	1	10,000	.05	.035	4.0	0.112 oz. in. at 6000 rpm	2.0 Oz.	....	10-A 8104-02
10	115	400	1	11,000	None (Shaded Pole)	.085	7.5	.096 oz. in. at 7000 rpm	3.5 Oz.	....	10-A 8101-01
11	115	400	1	12,000 Synch	0.1	.070	8.0	.08 oz. in. at 12,000 rpm	4.0 Oz.	....	11-A 8110-01
11	115	300-1800	1	10,000 (400 CPS)	0.5 (In Parallel)	.060 (400 CPS)	8.0 (400 CPS)	0.10 oz. in. at 9000 rpm (400 CPS)	5.0 Oz.	....	11-A 8223-01
11	115	400	1	60 Synch	0.1	.070	8.0	12 oz. in. at 60 rpm	7.75 Oz.	200:1	11-R 9003-02
11	26	400	1	30 Synch	2.0	0.35	8.0	14.5 oz. in. at 30 rpm	5.5 Oz.	195:1	11-R 9052-01
15	115	400	1	6,000 Synch	0.3	0.138	15.6	0.14 oz. in. at 6,000 rpm	8 Oz.	....	15-A 8120-01
18	115	400	1	12,000 Synch	0.35	0.148	14.7	0.41 oz. in. at 12,000 rpm	8 Oz.	....	18-A 8125-01
18	115	400	1	7600	0.6	0.45	4.5	2.45 oz. in. at 6800 rpm	24 Oz.	....	18-A 8126-01
18	115	60	1	8.5	1.0	0.175	17.5	30 oz. in. at 8 rpm	20 Oz.	405:1	18-R 9302-01
18	115	60	1	6.0	1.0	0.177	17.8	40 oz. in. at 5.75 rpm	20 Oz.	565:1	18-R 9302-02
21	115	400	1	22,000	1.0	0.75	80.0	1 oz. in. at 20,000 rpm	18.5 Oz.	....	21-A 8142-01
24	115	400	1	11,800	1.5	0.85	130.0	6.17 oz. in. at 10,800 rpm	29 Oz.	....	24-A 8161-01
24	115	60	1	20,000	None Required	1.2	175	8.9 oz. in. at 7,500 rpm	28 Oz.	....	24-U 8826-02
24	115	400	1	78	4.0	1.65	175	1530 oz. in. at 72 rpm	3 Lbs.	1528:1	24-R 9452-02
34	115	60	1	14,000	None Required	1.5	125	15 oz. in. at 4500 rpm	3-3/4 Lbs.	....	34-U 8901-02
34	115	60	1	1,780	3.75	0.45	50	12 oz. in. at 1700 rpm	4-3/4 Lbs.	....	34-A 8044-01

- All motors are continuous duty except Type 24-U-8826-02.
- −55°C to +85°C operating temperature range.
- All motors can be modified to meet your precise specification.
- For faster service, detail requirements when requesting further information.

Other products include servos, synchros, motor-gear-trains, resolvers, DC motors, servo mechanism assemblies, servo torque units, motor tachs, reference and tachometer generators, actuators and motor driven blower and fan assemblies.

John Oster

MANUFACTURING COMPANY
Your Rotating Equipment Specialist
Avionic Division
Racine, Wisconsin

EASTERN OFFICE
237 North Main Street
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Phone: Ivanhoe 3-4653
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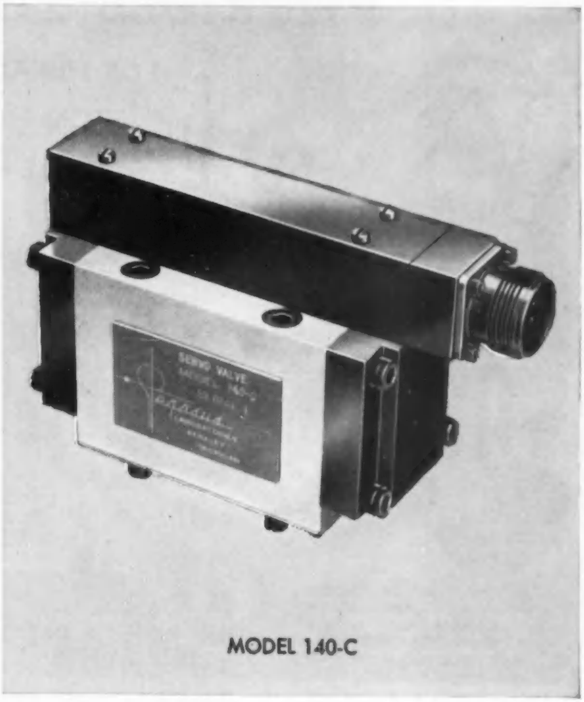
Burton Browne Advertising

Engineers For Advanced Projects: / Interesting, varied work on designing transistor circuits and servo mechanisms. Contact Mr. Robert Burns, Personnel Manager, in confidence.

MODEL 120-F



MODEL 140-C

PEGASUS ANNOUNCES THE MODEL 120-F and 140-C SERVO VALVES FOR INDUSTRIAL APPLICATION

The new Model 120-F and Model 140-C Servo Valves utilize a simplified force motor and valve spool boost system which requires very low input power yet provides extremely high valve spool stiffness.

This high spool stiffness, as well as the balanced hydraulic design, insures fine sensitivity and low null shifts over large ranges of operating pressure, temperature, and oil cleanliness. The valves need only 10 micron filtration and no dither for the specifications listed.

Because of the basic simplicity of the units, substantial price reductions have been made possible. We will be pleased to forward detail specifications and prices upon application.

SPECIFICATIONS

	MODEL 120-F	MODEL 140-C
Size:	1⅞ x 2¾ x 4¾	1⅞ x 3¼ x 5½
Operating Pressure:	200 to 3000 psi	200 to 3000 psi
Rated Flow:	5 g.p.m.	10 g.p.m.
Leakage:	.1 g.p.m.	.2 g.p.m.
Differential Current:	10 to 40 m.a.	10 to 40 m.a.
Coil Resistance:	1000 ohms	1000 ohms
Dead Band:	1%	1%
Hysteresis:	2%	2%
Null Shift:	1%	1%
45° Phase at:	90 c.p.s.	60 c.p.s.
90° Phase at:	120 c.p.s.	90 c.p.s.

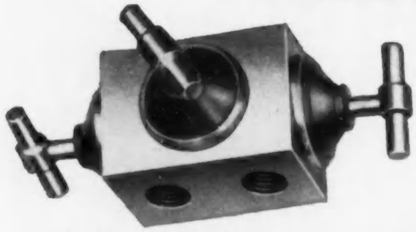
PEGASUS LABORATORIES, INC.

DESIGNERS AND MANUFACTURERS OF ELECTRO-HYDRAULIC SERVOMECHANISMS

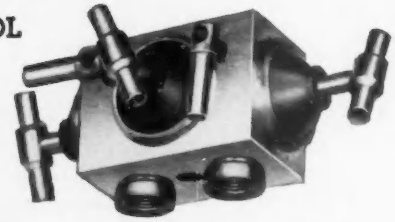
3690 W. ELEVEN MILE ROAD • BERKLEY, MICHIGAN

Packless "DEMI" Valves

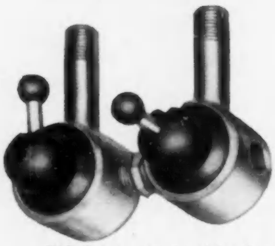
FOR MINIATURE CONTROL FROM PILOT PLANT TO PROCESS



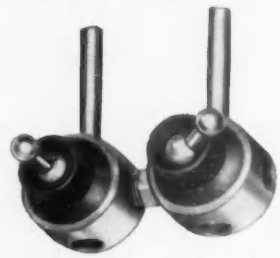
34-1 Compact Packless 3-Valve Manifold for meter and manometer applications (2-block and 1 by-pass valve ¼" NPT).



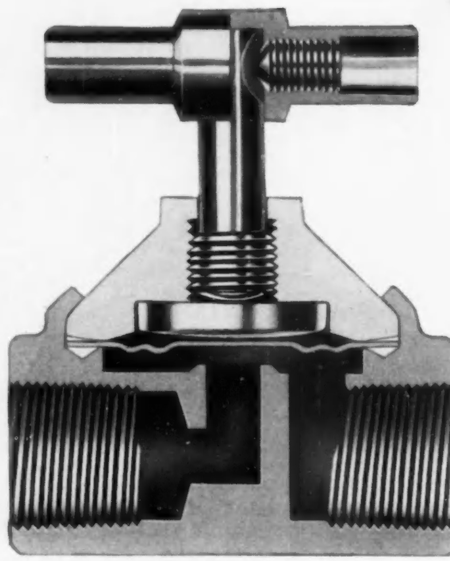
54-1 5-Valve Manifold designed for direct mounting on Miriam B-1103 manometer (2-block valves, 2 vent valves, and 1 by-pass valve).



H1-2 Two or more joined together with standard ⅛" pipe nipples form a header with individually controlled outlets, with single direction toggles which indicate at a glance which valves are open or closed.



H2-1 Special porting allows this model to be assembled in multiple numbers forming their own header. Two common ports are opened simultaneously when the toggle is tilted (⅛" NPT and ¼" tubing extension).



PATENT NO. 2,812,777

This basic patented packless design is employed in the designs shown, as well as many other variations available for your specific requirements. Specify body material when ordering.

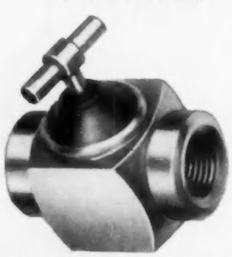
Write us for complete technical information, or for the address of our representative in your area.

REPRESENTATIVES IN PRINCIPAL CITIES

GEORGE W. DAHL COMPANY, INC.
86 TUPELO STREET, BRISTOL, R. I.

U-1 An ideal porting arrangement for minimizing fittings, equivalent of one pipe cross with one controlled outlet (shown with tube ends).

AM-1 Packless Angle Valve, (¼" male — ¼" female NPT).



G-8 Packless Globe Valve with standard internal ports. (Inlet and outlet ports, ½" NPT).

AT-1 Packless Globe Valve, all wetted parts TEFLON, in stainless steel housing with bolted bonnet, (¼" NPT).

G-9 Packless Globe Valve with panel-mount bonnet and extension stem equipped with anodized aluminum handle.

AR-16 Air Rate Indicator, range 0-2 SCFH. Unit is complete with toggle actuated packless valve, anodized aluminum bodies and protective column studs. (Other ranges available.)

AR-17 Air Rate Indicator similar to AR-16, but with needle valve for minute adjustment, ideal for purge meter application.

13-2 3-Way Valve designed for shuttling, blending or selecting. Stainless steel diaphragm, TEFLON seats, panel-mount bonnet and anodized aluminum handle, (¼" NPT).

GENERAL INSTRUMENT
SEMICONDUCTORS

Radio Receptor silicon diodes

IN ANY COMBINATION OF CHARACTERISTICS INCLUDING...

high speed · high conductance · high temperature · high voltage · high back resistance

General Instrument semiconductor engineering has made possible these new silicon diodes with a range of characteristics never before available to the industry. **Particularly outstanding is the all-purpose type 1N658 which offers uniform excellence in all parameters.** The RRco. diodes shown here are just a small sampling of the line — the complete list will be sent you upon request to Section CE-3

Code No.	Max. Fwd. Voltage Drop @ Indicated DC Current	Max. Rev. DC Cur. @ Test V.		Test Voltage	Min. Break-down Voltage*	Reverse Recovery
		25° C.	150° C.			
1N658	**1 @ 100 mA**	**.05 μA**	**25 μA**	**50V**	**120V**	**80KΩ in 0.3 μsec†**
1N457	1 @ 20 mA	.025 μA	5 μA	60V	70V	
1N458	1 @ 7 mA	.025 μA	5 μA	125V	150V	
1N459	1 @ 3 mA	.025 μA	5 μA	175V	200V	
DR668	1 @ 200 mA	.025 μA	5 μA	60V	80V	
DR669	1 @ 200 mA	.025 μA	5 μA	125V	150V	
DR670	1 @ 200 mA	.025 μA	5 μA	175V	200V	
			100° C.			
1N625	1.5 @ 4 mA	1 μA	—	10V	30V	15KΩ in 0.15 μsec‡
	—	10 μA	50 μA	20V	—	————
1N627	1.5 @ 4 mA	20 μA	100 μA	75V	100V	400KΩ in 1.0 μsec†
1N629	1.5 @ 4 mA	20 μA	100 μA	175V	200V	400KΩ in 1.0 μsec†
DR677	1 @ 100 mA	0.5 μA	25 μA	20V	30V	15KΩ in 0.15 μsec‡
DR673	1 @ 100 mA	0.5 μA	10 μA	75V	100V	400KΩ in 1.0 μsec†
DR675	1 @ 100 mA	0.5 μA	10 μA	175V	200V	400KΩ in 1.0 μsec†

*Reverse voltage at which a reverse current of 100 μA flows.
†When switching from 5 mA to −40V.
‡When switching from 5 mA td −20V.

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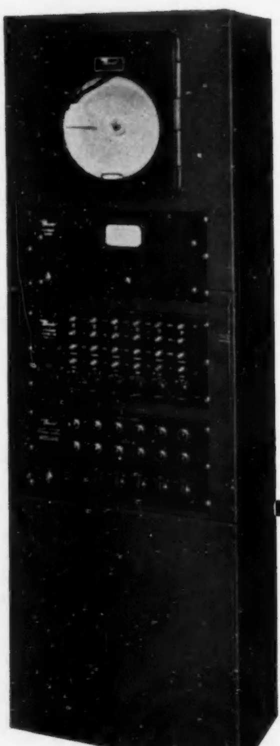

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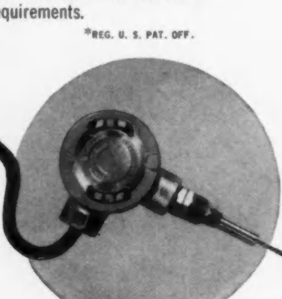

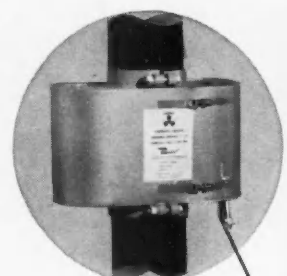

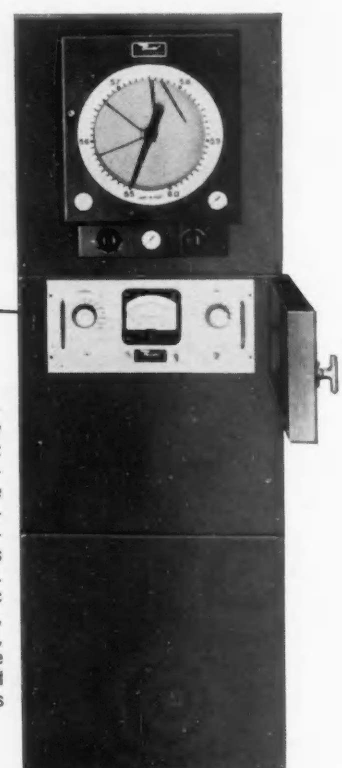

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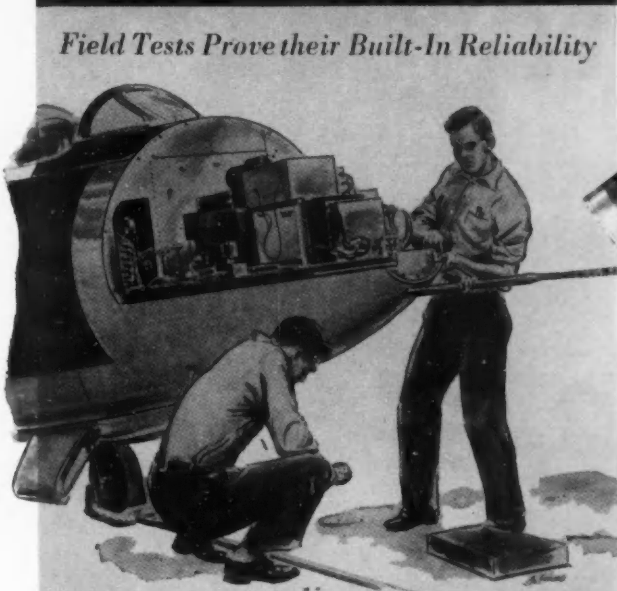

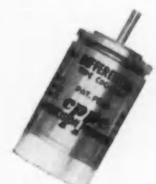

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Transmitter - Control Transformer	26	.111	.74	22.5	380	58 + j236	625 + j230	19	High impedance load on CT
Transmitter - Control Transformer	26	.111	.75	21.8	377	58 + j236		19	50° load on CT
Transmitter - Control Transformer	26	.110	.83	19.2	335	64 + j221		17	5° load on CT
Transmitter - Differential - CT	26	.134	1.70	18.5	340		740 + j364	40	Output to High Impedance
Electrical Resolver - Electrical Resolver	11.8	.115		7	120			52	Input to stator
Electrical Resolver - Electrical Resolver	26			15	280			53	Input to rotor

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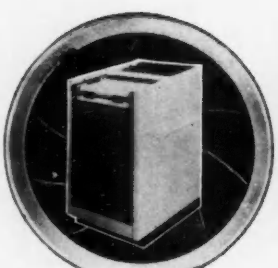

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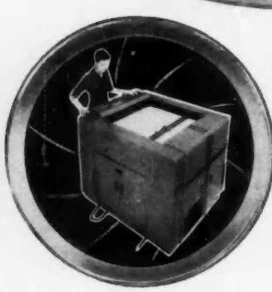
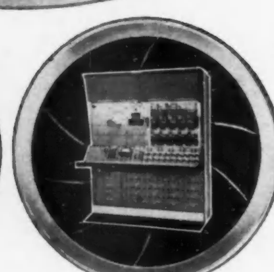
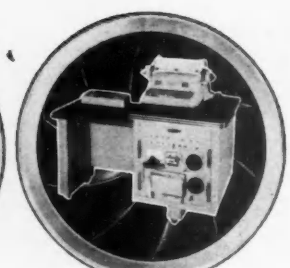


Dataplotter—Line plotter

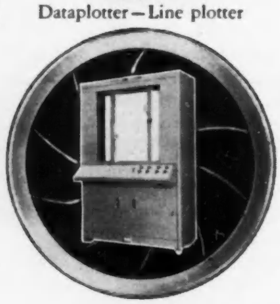


231 R Analog Computer



Analog Computer Automatic Digital Input-Output System

1100D or E Variplotter



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Control for Kilowatts

To the majority of industries reporting deep cuts in capital spending plans, the electric utility industry stands out as a bright exception on the economic horizon. Over the next ten months, the power companies will add a record-smashing 16,400,000 kilowatts of capacity at an estimated cost of $5.3 billion—a healthy increase over the $4.6 billion spent in 1957, the $3.8 billion in 1956, and the $3.6 billion in 1955. And the new installations reveal a decided trend towards computing-control to optimize generating and distribution processes.

Power companies grow

Here's just a partial rundown of what's planned for this year:

Digital data logger

• Louisiana Power & Light is installing an operational information system built by Daystrom Systems (estimated cost: $250,000) in its Sterlington station. Installation is scheduled for later in March. This system will monitor 350 variables (from temperature of generator bearings to boiler outputs), then run them through a transistorized digital computer with a magnetic-core memory. The general-purpose computer linearizes, scale-factors, and integrates each input signal.

Analog computing-control

• Southern California Edison has ordered a Leeds & Northrup desired-generation, computer-controlled system for its Alhambra load dispatcher's office. Purpose: to set generating levels of a number of stations at the most economic level. The equipment, which uses an analog computer, can preassign desired generation at any station as soon as the load comes on the utility's lines. Delivery is scheduled for the end of March.

• Florida Power & Light will install the "Flamingo", an L&N system, in October, at its Miami dispatching office. Carolina Power & Light has ordered a similar one for its Raleigh (N. C.) dispatching office.

• The Southern Co. will augment its Early Bird computer with automatic control so that about 30 generating stations will automatically respond to computer command for minimum cost of delivered power; eventually covering 44 stations.

• Public Service Electric and Gas Co. of N. J. has ordered two L&N, 600-point automatic data loggers for a big 580,000-kw station now under construction.

And still more

These announced projects are just part of the picture. In addition, several manufacturers are readying other automatic control systems for the expanding utilities.

▸ Westinghouse has built and tested an "economic dispatch

computer", which will determine optimum generating level for several utility generating stations.

▸ General Electric Co. installed several units of its "automatic dispatching systems" (ADS) last year and has orders for several more in 1958. ADS considers the significant factors incident to the loading of an electric utility's generation (system load, capacity, and maneuvering rates of turbines and boilers, line losses, spinning reserve, and cost of power production from each generator), then automatically makes adjustments as the system load changes.

▸ Minneapolis-Honeywell's automatic control system for utilities measures instantaneous demand for power throughout a system, then regulates the output of the generating equipment to meet that demand.

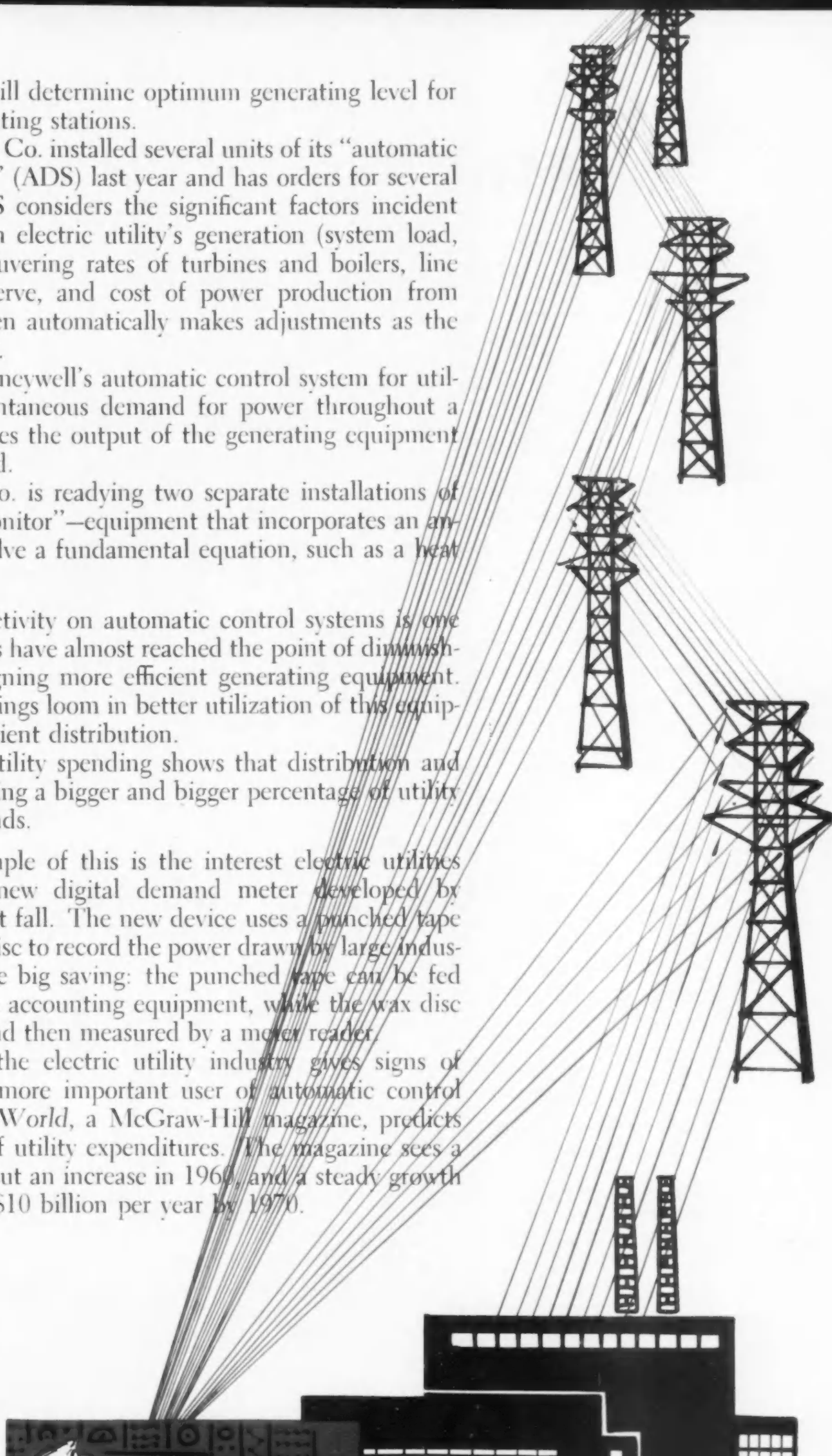
▸ Bailey Meter Co. is readying two separate installations of its "performance monitor"—equipment that incorporates an analog computer to solve a fundamental equation, such as a heat balance.

Behind all this activity on automatic control systems is one cogent fact. Utilities have almost reached the point of diminishing returns on designing more efficient generating equipment. Now the biggest savings loom in better utilization of this equipment and more efficient distribution.

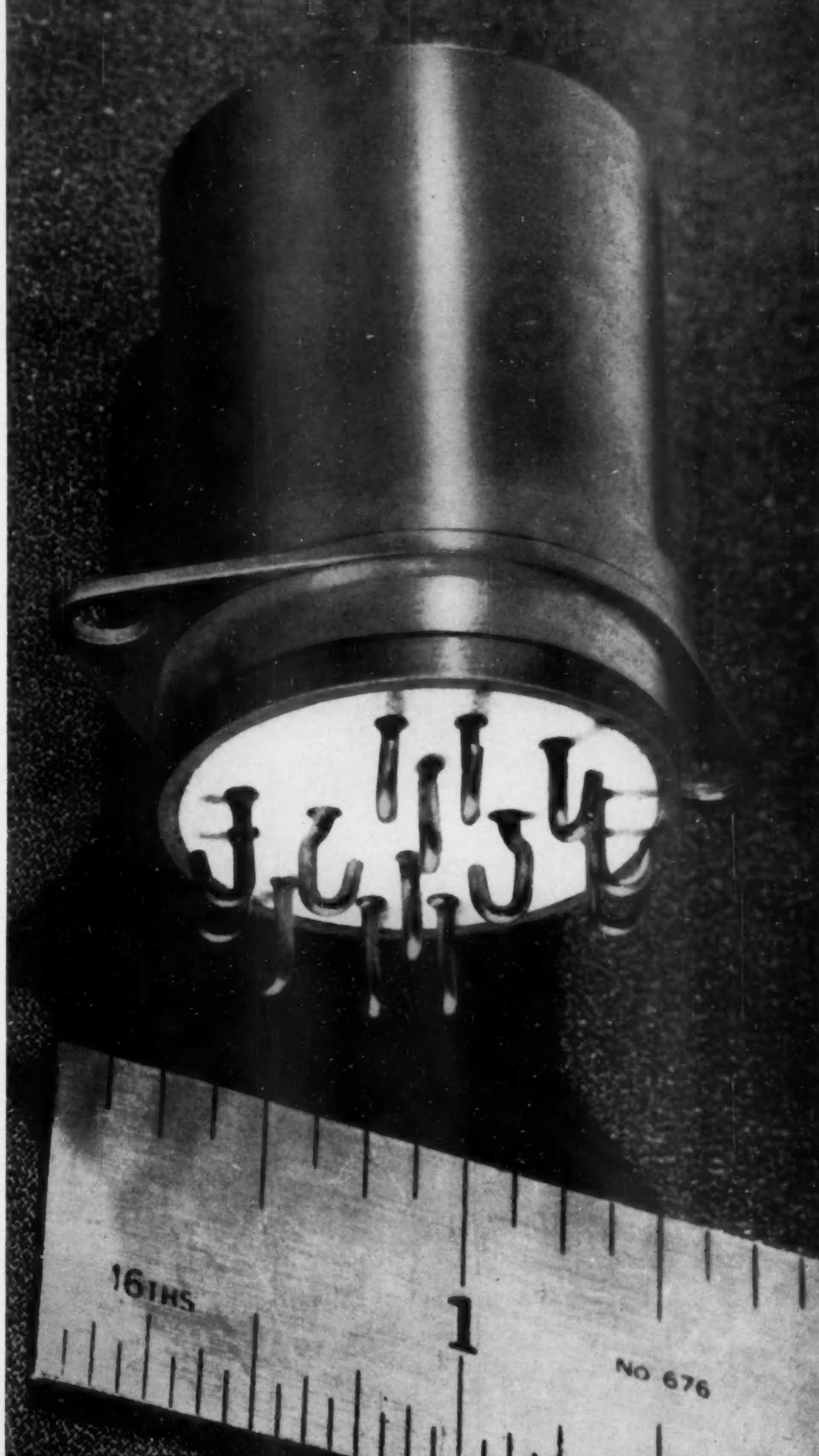
A close look at utility spending shows that distribution and transmission are taking a bigger and bigger percentage of utility capital spending funds.

One typical example of this is the interest electric utilities have shown in a new digital demand meter developed by Fischer & Porter last fall. The new device uses a punched tape instead of a waxed disc to record the power drawn by large industrial customers. One big saving: the punched tape can be fed right into automatic accounting equipment, while the wax disc must first be read and then measured by a meter reader.

For the future, the electric utility industry gives signs of becoming an even more important user of automatic control systems. *Electrical World*, a McGraw-Hill magazine, predicts continued growth of utility expenditures. The magazine sees a slight dip in 1959, but an increase in 1960, and a steady growth thereafter—passing $10 billion per year by 1970.



FOR THE FIRST TIME a new



GENERAL SPECIFICATIONS

Size	1.79" long (maximum) 1.063" in diameter (maximum)
Weight	3.0 ounces
Nominal Operating Voltage	26.5 volts
Contact Metal	gold alloy
Contact Bounce	less than 250 miscroseconds
Temperature Rating	−65°C to +200°C
Shock	55 g
Vibration	2,000 cps at 25 g

Control
ENGINEERING

MARCH 1958

What do your control dollars buy?

The literature of the control engineering field offers little specific advice on evaluating the economic return on measurement and control systems. The reason for this lack is the overwhelming emphasis that has been placed on solving the technical, rather than economic, problems of measurement and control. The control engineer has been conditioned during the last ten years by demands for increased yield—measured in terms of industrial productivity or weapons kill—to apply measurement and control equipment to improve *physical* performance. The performance indices were dynamics, accuracy, operating speed, capacity, reliability, safety, and uniformity. They could be measured and described with numbers. Improved *economic* performance was, of course, a general requirement, but the control engineer was not pressed to evaluate it numerically.

Now he is, because industry has shifted its emphasis from productivity to production economy. And he will be pressed hard until the current economic decline reverses under the stimulus of defense spending, new orders to replenish depleted inventories, and revitalized plans for capital investment in plants. The control engineer who will not realistically appraise a control system as a means for effecting operating economies is not giving his job all of his creative ability. And what is perhaps even more important to him, he is missing an opportunity to demonstrate his own value in dollars, a performance-rating scale that everyone understands. Aware of the lack of emphasis on this phase of measurement and control, the editors of Control Engineering have started publishing articles that bring out the economic evaluation problem and show how to tackle it. The December '57 issue contained an article entitled "Why Control System Bids Vary", page 87. The February '58 issue offered "Three Ways to Estimate Instrumentation Cost of Process Plants", page 88. Next on the docket is coverage of the principles of figuring the reductions in operating cost that investment in measurement and control equipment can buy.

The control engineer must continue to work to the physical performance indices that he has developed. But he must add what is now the most important index of performance—how much reduction in operating costs will money spent on control equipment buy?

The Editors

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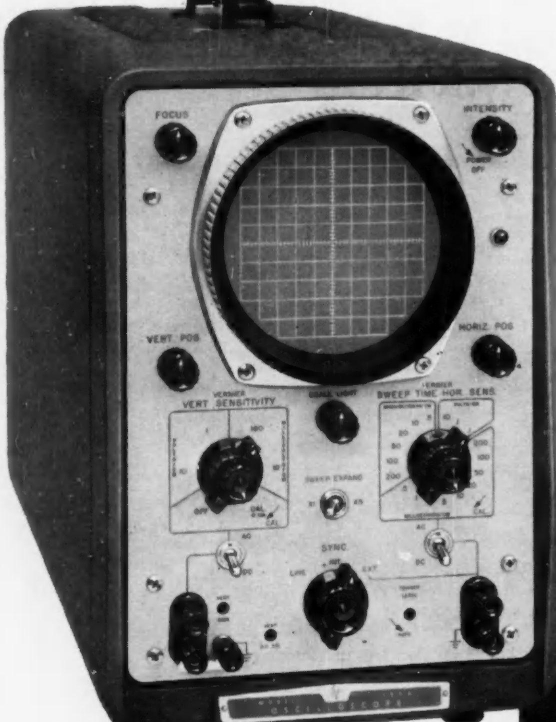

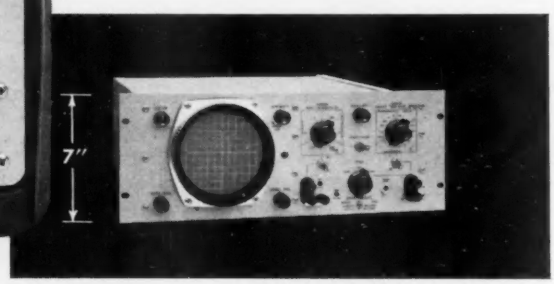

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These new instruments combine calibrated precision for lab work with brute ruggedness for the production line; the rack-mounted 120AR is ideal for fixed installations and test consoles.

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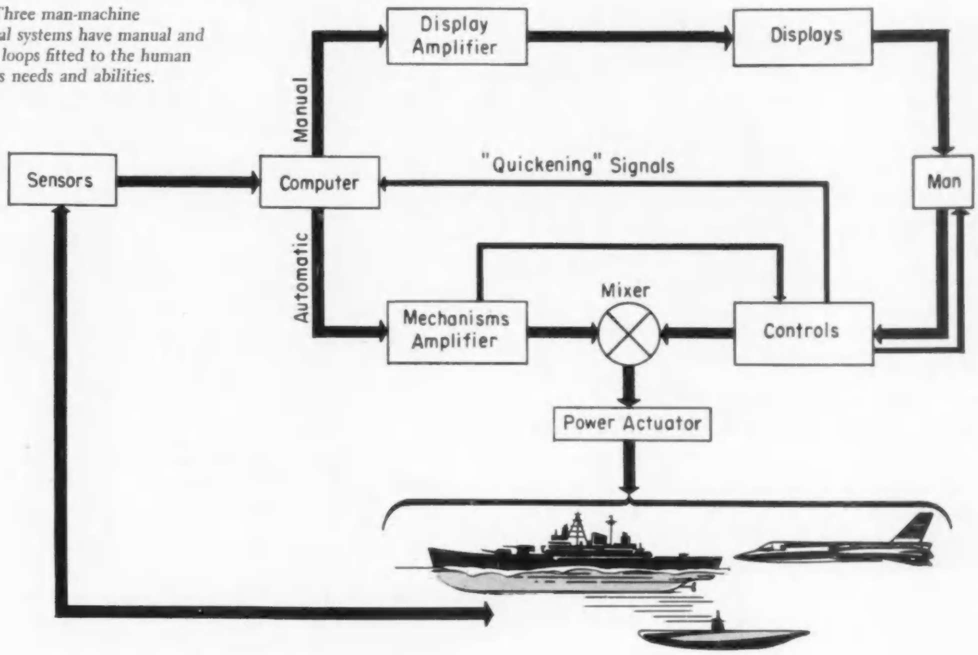


FIG. 1. Three man-machine navigational systems have manual and automatic loops fitted to the human controller's needs and abilities.

Control in Man-Machine Systems

GEORGE W. HOOVER, Office of Naval Research*

Is man moving in or out of control systems?
Is he becoming a monitor or a controller of machines?
The author maintains that there is no system in which a man does not exercise control, if only during critical start-up or launching periods. He declares that because of this, the first big step, after setting system objectives, is to set down display requirements. The specifications for sensors, manual control loops, and automatic control loops then become functions of the display specifications.

* The opinions or assertions contained in this paper are the private ones of the writer, and are not to be construed as official, or reflecting the views of the Dept. of the Navy or the Naval service at large.

Control breaks down into two main divisions: manned systems and unmanned, or remote control, systems. Each of these further divides into automatic and manual control.

Manned system uses human decisions

The manned system calls for a closed loop in which the man acts either as a continual decision-maker in series with the elements of the control loop, or a monitor in parallel with the elements. When the man is in series, the system is under manual control. When he is in parallel, the control is automatic. In either case he retains some degree of decision-making power.

The manned system in Figure 1 starts with a group of sensors which feed inputs to a central computer. The computer output includes information supplying a display system by way of a display amplifier, and a control function by way of a mechanisms amplifier. Observing the displays, the man operates the machine through a set of manual controls. The outputs from the manual controls, mixed with the

output of the mechanisms amplifier, go on to the machine power actuators. A feedback from the machine to the sensors closes the overall loop.

In addition to the main loop there are feedbacks from the manual controls to the computer in the form of "quickening", or rate and rate of rate signals, and from the manual controls to the man in the form of acceleration forces.

This is the basic man-machine system and follows the logic that in any operating system certain data must be sensed, then computed, amplified, displayed, and viewed, and finaily controls must be actuated to operate the machine.

Unmanned system adds remote communication links for manual control

The unmanned or remote man-machine system differs from the manned system in that there is a transmitter between the computer and the display amplifier and a receiver between the manual control and the control mixer. Here again the man can act as a direct controller with the system in a manual mode or as a monitor when it is set for automatic control.

The manual side of the system is made physically remote from the machine being controlled by some means of remote signal transmission. Even in this configuration the man-machine system is still a closed loop, the only difference being in the method of connecting the automatic and manual portions of the entire system. In the case of a guided missile, what would normally be the control station or cockpit is located either in an airborne station or on the ground. Where the system is self-contained for flight, the manual portion is simply left behind when the missile is launched.

To be considered "automatic", the automatic side, in contrast to the manual side, must be operating at all times, even though capable of being overridden by the manual mode. This side of the loop operates independently of the manual portion and would be employed in a completely unmanned system such as a ballistic missile (when in flight).

The operation of the automatic side is determined by the programming of the computer and can be only as versatile as the program. If a single operational path is set into the computer memory, the machine can follow only this path and has absolutely no decision-making power except to evaluate the sensor data. If several possible paths are programmed, the system can select, as a function of the accuracy of the inputs, which path it should follow. The finite number of possibilities which can be programmed limits the flexibility of the automatic control. Limited flexibility is not a disadvantage in every case because there are instances in which only a few finite paths really should be followed. An example is the application of automatic loops to quality control of a manufacturing process. If the computer is designed for interchangeable program cards, the flexibility limit is no concern.

First, look at the real objectives and ask why

All man-machine systems are fundamentally identical. Their rates, total operating-cycle times, and

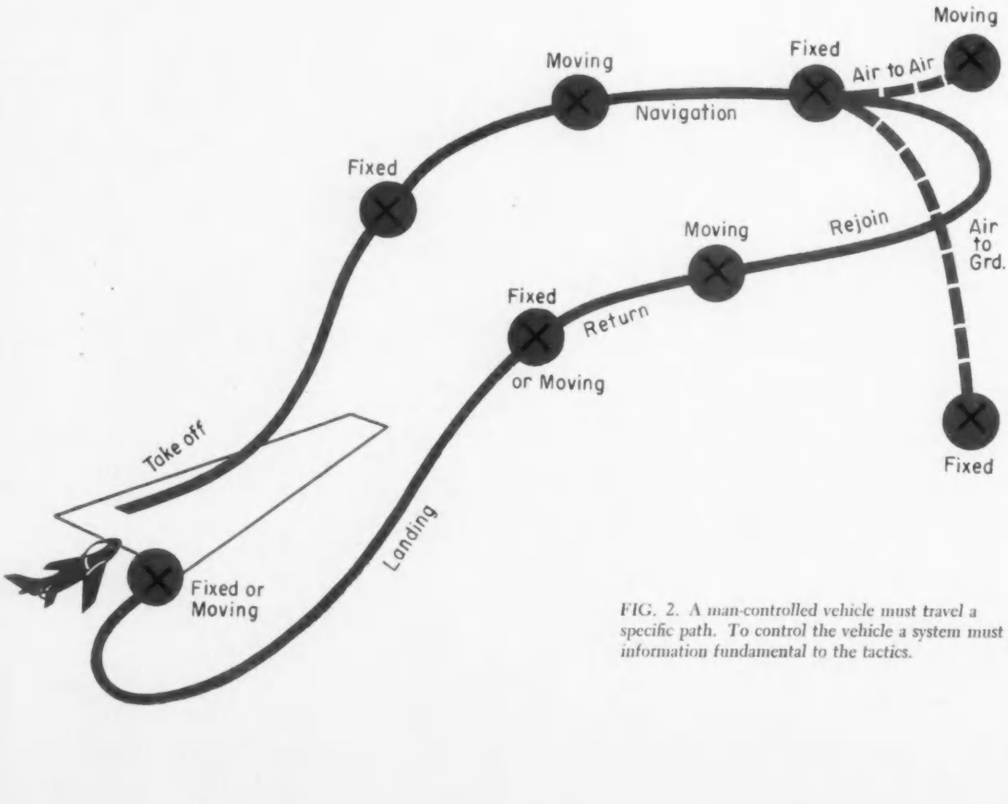


FIG. 2. A man-controlled vehicle must travel a specific path. To control the vehicle a system must provide information fundamental to the tactics.

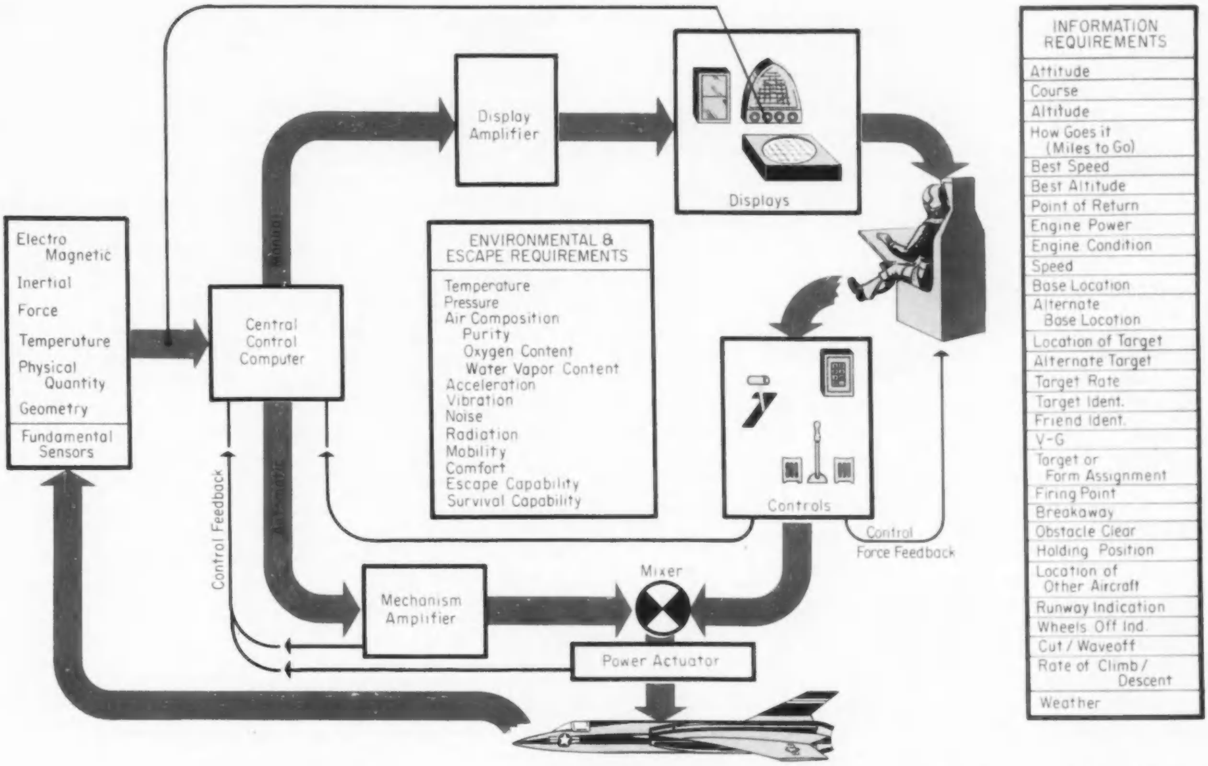


FIG. 3. A man-machine system integrates essential functions to minimize redundancy.

their specific sensors vary. Compare the airplane, ship, and submarine shown in Figure 1. The requirement common to all of them is to orient the vehicle in space about three axes. The ship differs from the airplane and the submarine in that it is fixed to the surface and therefore has one less requirement for operation. For all practical purposes, change in elevation is removed. For the other two, the basic requirement is to move the vehicle's center of gravity from one point to another along some specific path such as that shown in Figure 2. Whatever the makeup of the system, it must conform to the laws of motion.

Since the vehicle is to be man-controlled, the control system must also meet the requirements for information, comfort, and safety established by the human controller. The information requirements must be stated in the absolutely fundamental terms of what information is necessary to control the machine, and not in terms of existing or contemplated equipment.

For example, in determining the information necessary to get an airplane into the air, one requirement is to keep the airplane aligned with the runway. The information necessary here is—where is the plane going with respect to lateral position on the runway?—, rather than what is its directional gyro heading? Continuing to ask "why" establishes more requirements.

If, for instance, this question were put to a submarine controller, "What do you need to know in order to dive?", he would undoubtedly answer that he needed to know the angle of the dive planes. If the questioning stopped here, the control engineer would specify a dive plane angle indicator. However, if the questioning continued, the controller being asked why he needed dive plane angle, would probably say that he needed it as an index to determine the dive angle of the submarine. Why does he need to know the dive angle of the submarine? Because he wants to dive at a safe rate and be able to level off without overshooting the depth desired. The answer to "why" here is a tactical one and is the reason for making the dive. The submarine controller wants to know how to proceed along a path which is safe and from which he will level out at the correct depth. The requirement calls for dive path, not dive plane angle—really only one factor in the overall equation. This type of reasoning must be carried out for each mode of operation of the machine in order to meet the man's total information requirements. Since the man must control the machine, design must start with meeting his requirements rather than forcing him to conform to machine requirements.

Display is the key

After establishing the information and environmental requirements comes the system display specification. The display must be such that it demands no integration on the part of the human controller;

in fact, it establishes the technical requirements of the entire system. To create the display, the control engineer must spell out the critical sensors; he must determine the equations for presenting integrated information; from the equations he can then determine the control functions and the actuations which will bring about corrections in machine operation.

Automatic functions

The automatic side of the system must, in every case, be designed as a complete system. Figure 3 shows one. Previously "automatic pilots" or "automatic controls" were simply added to already-existing basic control systems. This procedure complicated the situation by adding equipment, which in turn increased weight, size, and cost, and magnified maintenance problems. The approach of adding "black boxes" adds sensors, computers, displays, and redundant control actuators which operate through the main system. In a simple machine the addition of equipment is acceptable, but in a complicated machine such as a high-performance airplane, the required sensors, computers, and controls rapidly increase in number and, for the most part, are redundant with respect to other elements already in the basic system.

Unintentional redundancy is eliminated from an integrated system because the control function is just another output of the central computer. No sensors or controls are added and the only change in basic system is in programming of the computer.

FIG. 4. Example of an integrated system with display and manual controls.

Manual functions

On the manual side, the control engineer must consider, first, what must be controlled, and, second, how the human best uses his hands and feet for the most accurate control and with the least fatigue. Little thought has been given to improving manual control functions in an aircraft. They have remained practically the same since the original system was designed, i.e., a central stick for pitch and roll, rudder pedals for yaw, and a throttle quadrant on the left for engine control. How the rudder pedals first became designed as they are today is hard to say, because their operation is exactly the reverse of such things as sleds and bicycles. There is some doubt as to whether rudder control is needed at all, but if it is, yaw might be manipulated by the stick. At any rate, considerable study must be made to determine the basic requirements of an idea like this, and the most efficient means of meeting them. Preliminary studies indicate that there is a possibility of moving the stick to the right of the control console and using it for displacement about all three axes—pitch, roll, and yaw.

Army-Navy Instrumentation Program demonstrates the approach

Determination of control specifications—not solely by invention and not entirely by test and evaluation, but by including them in an approach which starts with stating the human controller's information needs—in turn determines display requirements, and then establishes the technical control requirements. It has worked quite well. An outstanding example of the technique is the system developed under the Army-Navy Instrumentation Program and shown in Figure 4. Through it the control system has been integrated so that part of the control action is in the sensors, part is in the computer, and part is in the fully-coordinated and simplified manual controls. The control functions have no redundancy. There is no addition of equipments. The controls are adequate and compatible because they were designed to meet the pilot's requirements rather than an existing system in which man was not considered an important component.

Controls cannot be added as a final touch to complete a man-machine system. They are adequate only if when actuated they give the proper response positively, without delay and without reversals. Such controls can be built only if they are designed as an integral part of the entire system.

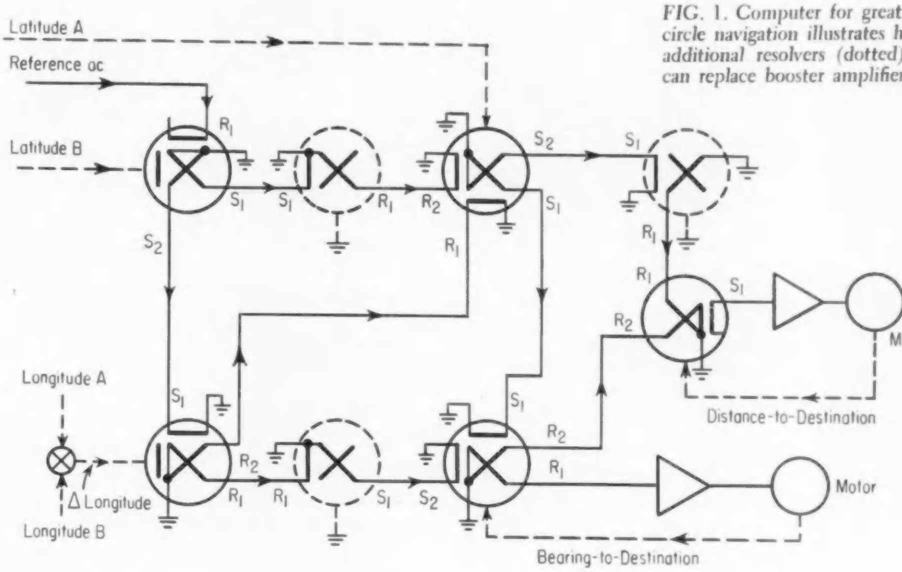


FIG. 1. Computer for great circle navigation illustrates how additional resolvers (dotted) can replace booster amplifiers.

Cascading Resolvers Without Booster Amplifiers

JACK GILBERT, Norden-Ketay Corp., Norden Laboratories Div.

THE GIST: The so-called "booster" or isolating amplifiers normally required between ac resolvers that are cascaded may not be necessary if the computing precision needed is in the order of 1 percent or less. This article presents formulas by means of which the effect of cascading any practical number of resolvers can be calculated, and, in many cases, those expensive amplifiers saved.

In ac bombing and navigation computers it is quite often necessary to transform a given vector through several resolvers in cascade before it has the desired form. The final vector, by itself or with another vector, then is generally used to drive a servo and output shaft to a computing null.

A typical schematic for such a situation is shown in the great circle computer[3] of Figure 1. Five resolvers, in solid outline, drive servos which compute distance and bearing to destination, from inputs of latitude and longitude of home and destination.

Loading problems

In high precision applications, an isolating or booster amplifier would normally drive each resolver. Each resolver output lead would then look into a high resistance load instead of another resolver. For the example of Figure 1, this would require seven costly resolver amplifiers. And reliability would be reduced by the increased number of components and active elements.

Where the application permits medium precisions of the order of 1 percent full scale, the resolver am-

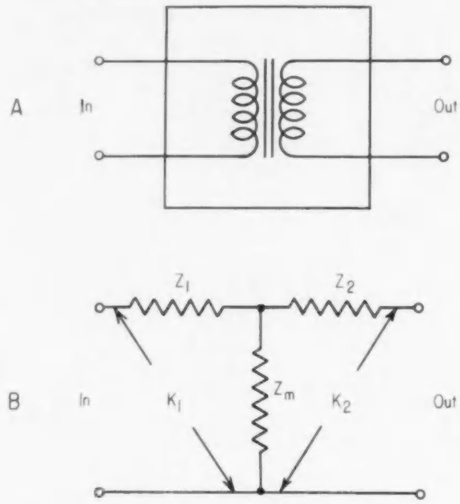


FIG. 2. A—resolver is a transformer which can be represented by: B—an equivalent-T network.

plifiers can be eliminated as long as the loads for each of the resolvers are identical in magnitude and phase. Since several resolvers in cascade may appear as a load of only a few hundred ohms, small differences in load can seriously impair computing accuracy: the balance requirements become more critical as the magnitude of the load impedance decreases.

In Figure 1, three calibrating resolvers (dotted outlines) are added to adjust output scale factors and obtain a balanced load for each resolver output. There are thus five resolvers cascaded for both distance and bearing computations, for a total of eight units. The substitution of three passive resolvers for seven costly high-gain amplifiers is well worthwhile.

A resolver can be described in terms of an "equivalent-T" network by using conventional filter and transmission-line analysis theory[1,2]. The equivalent-T parameters are shown in Figure 2. As used in this article, K_1 is the input impedance with the output terminals open-circuited; thus,

$$K_1 = Z_1 + Z_m$$

Likewise, K_2 is the impedance looking into the output terminals with the input terminals open-circuited:

$$K_2 = Z_2 + Z_m$$

Note that if a rotor winding is the input, a stator is the output, and vice versa.

The input impedance with the output terminals shorted is called K_{IS}, and

$$K_{IS} = K_1 + \frac{K_2 Z_m}{K_2 + Z_m}$$

The three impedances of the T-circuit can be defined, by eliminating Z_1 and Z_2 from the expression for K_{IS}, as

$$Z_m = \sqrt{(K_1 - K_{IS})(K_2)}$$
$$Z_1 = K_1 - Z_m$$
$$Z_2 = K_2 - Z_m$$

Measurement of resolver parameters

The effective values of K_1, K_2, and K_{IS} can be determined by making two voltage measurements and a phase measurement with the circuit of Figure 3. The terminals of the resolver to be measured are connected as shown, keeping the applied voltage low enough to limit the secondary current to its rated value when measuring K_{IS}.

In Figure 3, E is the voltage across the unknown, and is approximately equal to E_1. E_2 is the voltage across the 1-ohm resistor, which is directly proportional to the current through the unknown. The phase angle is $\tan^{-1}(X/R)$, where X is proportional to the imaginary component and R is proportional to the real component of the impedance being measured. Both X and R can be read on the Phazor meter. Thus,

$$Z = \frac{E_1}{E_2} \angle \tan^{-1} \frac{X}{R}$$

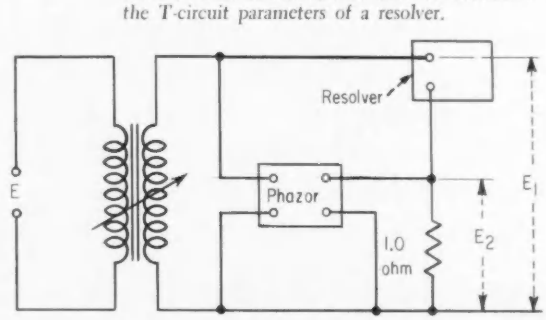
For an equivalent-T network, three measurements are necessary to solve for the three unknowns, Z_1, Z_2 and Z_m.

Analysis of resolver connections

Knowing the equivalent-T parameters of a resolver, the transfer ratios and complex impedances of any number of cascaded resolvers in any configuration can be derived from conventional network theory. The formulas shown for resolver connections in this article were derived from the simplified formulas for cascaded networks given in Reference 1. These simplified formulas work well because two assumptions were made at the outset: first, that the generator impedance Z_S in Figures 4 and 5 (see special box), was zero because the resolvers were excited by line voltage; and second, that the final load impedance, Z_R, was infinite because the last resolver looks into a practical open-circuit represented by the servo amplifier.

If these assumptions are not applicable, the general formulas given in Reference 1, which involve reflec-

FIG. 3. This circuit can be used to determine the T-circuit parameters of a resolver.



FORMULAS FOR CASCADED RESOLVERS

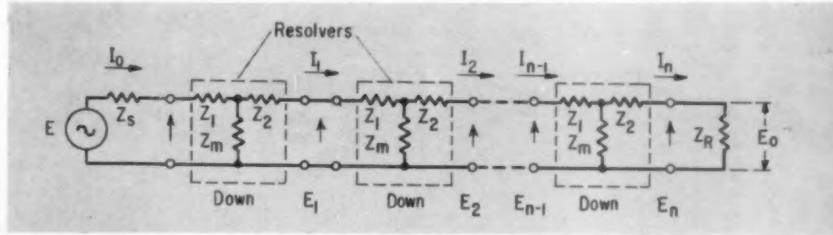


FIG. 4. In the iterative connection, all resolvers are connected step-down (or step-up).

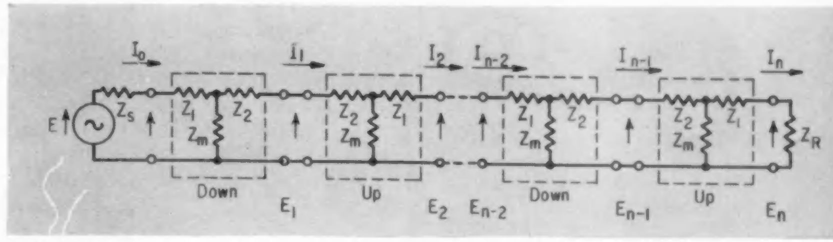


FIG. 5. In the image connection, resolvers are connected alternately step-down and step-up.

Formulas for iterative connection of n cascaded resolvers

Transfer ratio

$$\frac{E_0}{E} = \frac{(1 + Z_{02}/Z_{01})e^{-n\lambda}}{(1 + Z_{02}/Z_{01} \cdot e^{-2n\lambda})} \qquad (1)$$

For $n \gg 1$,

$$\frac{E_0}{E} = (1 + Z_{02}/Z_{01})e^{-n\lambda} \qquad (1a)$$

Input impedance

$$Z_{IN} = Z_{01}\frac{(1 + Z_{02}/Z_{01} \cdot e^{-2n\lambda})}{(1 - e^{-2n\lambda})} \qquad (2)$$

For $n \gg 1$,

$$Z_{IN} \cong Z_{01} \qquad (2a)$$

Definitions

$$\frac{Z_{02}}{Z_{01}} = \frac{\sqrt{K_a^2 - 4} - K_b}{\sqrt{K_a^2 - 4} + K_b} \qquad (3)$$

$$Z_{01} = \frac{Z_m}{2}\left(\sqrt{K_a^2 - 4} + K_b\right) \qquad (4)$$

where Z_{01} is the characteristic impedance of the T section looking into the rotor.

$$e^{\pm\lambda} = (K_a \pm \sqrt{K_a^2 - 4})/2 \qquad (5)$$

where $e^{-\lambda}$ is the propogation function which gives the attenuation and phase shift per section.

$$K_a = (K_1 + K_2)/Z_m \qquad (6)$$

$$K_b = (K_1 - K_2)/Z_m \qquad (7)$$

(K_1, K_2, and Z_m are the parameters of the equivalent T)

Formulas for image connection of n cascaded resolvers

Transfer ratio

n odd

$$\frac{E_0}{E} = \sqrt{\frac{K_2}{K_1}} \cdot \frac{1}{\cosh n\theta} \qquad (8)$$

or

$$\frac{E_0}{E} = 2\sqrt{\frac{K_2}{K_1}} \cdot \frac{e^{-n\theta}}{1 + e^{-2n\theta}} \qquad (8a)$$

For $n \gg 1$,

$$\frac{E_0}{E} = 2\sqrt{\frac{K_2}{K_1}} \cdot e^{-n\theta} \qquad (8b)$$

n even

$$\frac{E_0}{E} = \frac{1}{\cosh n\theta} = \frac{2e^{-n\theta}}{1 + e^{-2n\theta}} \qquad (9)$$

For $n \gg 2$,

$$\frac{E_0}{E} \cong 2e^{-n\theta} \qquad (9a)$$

Input impedance

n, even or odd

$$Z_{IN} = Z_{I1} \cdot \cosh n\theta$$

$$= Z_{I1} \cdot \frac{(1 + e^{-2n\theta})}{(1 - e^{-2n\theta})} \qquad (10)$$

For $n \gg 1$,

$$Z_{IN} = Z_{I1} \qquad (10a)$$

Definitions

$$e^{\pm\theta} = (\sqrt{K_1K_2} \pm \sqrt{|Z|})/Z_m \qquad (11)$$

$$Z_{I1} = \sqrt{K_1\,|Z|/K_2} \qquad (12)$$

$$Z_{I2} = \sqrt{K_2\,|Z|/K_1} \qquad (13)$$

where

$$|Z| = K_1K_2 - Z_m^2 = Z_{I1}Z_{I2} \qquad (14)$$

Formulas for n cascaded symmetrical resolvers

For such networks, $K_1 = K_2$, and

$$Z_{01} = Z_{02} = Z_{I1} = Z_{I2} = Z_0 \qquad (15)$$

Transfer ratio

$$E = \frac{2e^{-n\theta}}{1 + e^{-2n\theta}} = \frac{1}{\cosh n\theta} \qquad (16)$$

For $n \gg 1$,

$$\frac{E_0}{E} = 2e^{-n\theta} \qquad (16a)$$

Input impedance

$$Z_{IN} = Z_0 \operatorname{ctnh} n\theta \qquad (17)$$

$$Z_{IN} = Z_0\frac{(1 + e^{-2n\theta})}{(1 - e^{-2n\theta})} \qquad (17a)$$

For $n \gg 1$,

$$Z_{IN} = Z_0$$

Definitions

$$Z_0 = \sqrt{K_1^2 - Z_m^2} \qquad (18)$$

$$e^{\pm\theta} = K_1 \pm \sqrt{K_1^2 - Z_m^2}/Z_m \qquad (19)$$

$$\cosh\theta = K_1/Z_m \qquad (20)$$

NOTE: Equations 1 through 20 may be used for any value of n. For one section only,

$$\frac{E_0}{E} = \frac{Z_m}{K_1} \qquad Z_{IN} = K_1$$

tion coefficients in both directions, must be used instead; the calculations then become much more complex.

Basically, there are two forms of connections for cascaded resolvers. One, called the iterative connection, uses all resolvers in the same sense, i.e., all step the input voltage up or down. The other form, called the image connection, alternates the resolvers with regard to their step-up or step-down property.

Most of these formulas can be derived by conventional circuit analysis, but the method shown here emphasizes the attenuation and impedance parameters and gives better insight into the behavior of cascaded resolvers.

There is a special case, involving resolvers with a 1:1 transformation ratio. The formulas for all cases are presented with Figures 4 and 5 on page 87.

Application to size-8 resolvers

The 8-A-1 resolver has a normal transformation ratio of about 2.6:1 and a phase shift of plus 20 deg when connected open-circuit and rotor-excited, and the 8-A-4 resolver has a transformation ratio of about 1:1 and a phase shift of plus 20 deg.

The catalog values and measurements described previously were used to calculate the T-circuit parameters (Table I) for each resolver, and the behavior of each resolver under various conditions. The calculations for the 8-A-1 resolver will be shown in some detail for the iterative connections, to illustrate the use of the formulas. Calculated results were compared with experimental results taken on actual configurations. For the iterative connection of 8-A-1 resolvers connected step-down (magnitudes are in ohms and angles are in degrees) the formulas yield:

$$K_a = 2.99\angle\underline{-17.7}$$

$$K_b = 1.95\angle\underline{-21.8}$$

$$Z_{01} = 594\angle\underline{+58.6}$$

$$Z_{02}/Z_{01} = 0.131\angle$$

$$e^{-\lambda} = 0.362\angle\underline{+22.7}$$

Attenuation per section $\cong$ 0.33 (ratio)

Phase shift per section $\cong$ +22.7 deg

$$\frac{E_0}{E} = \frac{1.12\angle\underline{-3.2}\cdot e^{-n\lambda}}{1.0 + 0.131\angle\underline{-28}\cdot e^{-2n\lambda}}$$

and for $n \gg 1$,

$$\frac{E_0}{E} = 1.12\angle\underline{-3.2}\cdot e^{-n\lambda}$$

$$Z_{IN} = \frac{594\angle\underline{58.6}\cdot(1+0.131\angle\underline{-28}\cdot e^{-2n\lambda})}{1-e^{-2n\lambda}}$$

and for $n \gg 1$,

$$Z_{IN} = 594\angle\underline{+58.6}$$

These results are plotted in Figure 6. The complex transfer ratio is compared to the experimental results, shown dotted. The agreement is quite remarkable considering that the impedance measurements were taken on only one resolver to an accuracy of only about 3 percent. Experimental results on all other plots were so close to the theoretical results that only the latter are shown.

The formulas given were then assumed to correspond to reality and used to calculate the errors due to unbalance of load and tolerance of components, quadrature voltage effects, etc.

In all cases, the experimental data taken agreed with the theoretical values to an average of 2 percent on amplitude, and to about 3 deg on phase. This is well within the measurement and component tolerances for impedance and voltage parameters.

Figure 6 shows that connecting the 8-A-1 resolver iterative-down results in a prohibitive loss of signal —about 45 to 1 for four resolvers. This result agrees exactly with the open-circuit attenuation for four step-down resolvers, indicating that passive loading has little effect in the step-down connections.

Figure 7 shows that the image connection, which alternates step-down and step-up transfers, reduces the above attenuation by a factor of almost 8 for four resolvers. Clearly the image connection is preferable to the iterative-down connection.

Figure 8 compares the image connection with the iterative-up connection. The iterative connection gives twice as much signal for two resolvers and about the same signal for four resolvers; from that point on its signal becomes increasingly less because of its higher attenuation rate. Furthermore, its impedance plot (Figure 9) shows that the iterative-up impedance is only about $\frac{1}{6}$ that of the image impedance (Figure 10), making it prohibitive from the current supply standpoint.

It can be concluded then that the image connection is superior to either iterative connection for

TABLE 1—EQUIVALENT-T PARAMETERS FOR TYPICAL RESOLVERS

Parameters	Resolver Type		
	8-A-1 (2.6 : 1) (Rotor Excited)	8-A-4 (1 : 1) (Rotor Excited)	
K_1	280 + j600	280 + j600	Catalog Values
K_2	38 + j136	200 + j660	Catalog Values
Z_m	26.6 + j268	65 + j595	Norden Measurement

FIG. 7

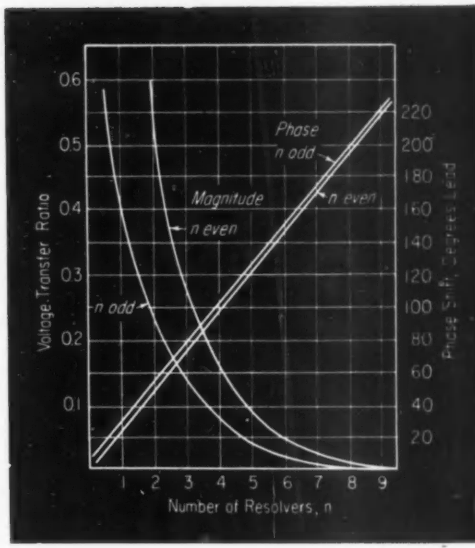


FIG. 6

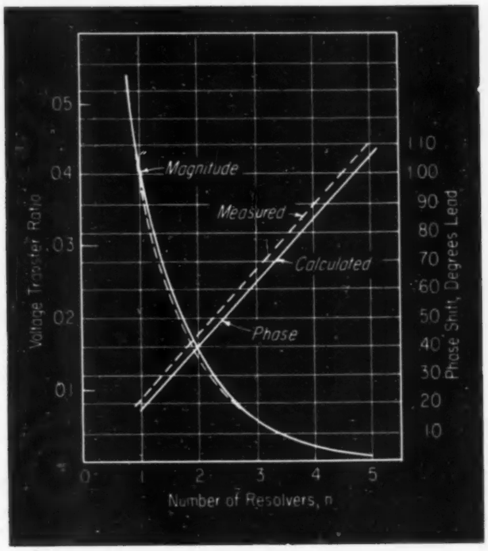


FIG. 8

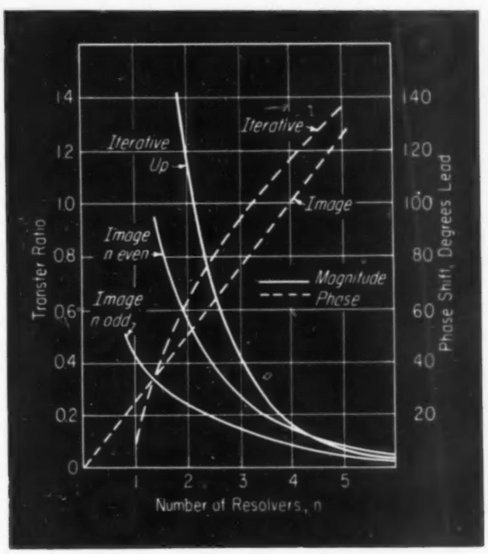


FIG. 6. Transformation ratio and phase shift for one to five cascaded resolvers in the iterative step-down connection.

FIG. 7. Transfer ratio magnitude and phase for one to nine image-connected resolvers.

FIG. 8. Comparison of transfer ratios for one to six cascaded resolvers in the iterative step-up and image connections.

step-down resolvers, especially when more than two units are used. And when driving power is scarce, the image-down connection is preferred in order to minimize current drain. When n is even, the same voltage results for either image connection, as can be seen by interchanging K_1 and K_2 in Equations 9, 11, and 14.

The symmetrical resolver (8-A-4)

The transfer ratio plot of the symmetrical resolver shows a decided loss of signal in the iterative (up or down) connection, and, since the resolver is symmetrical, in the image connection, too. The signal attenuation of about 7:1 for four symmetrical resolvers, is about the same as for the 8-A-1 resolver connected on the image basis (compare Figure 11 with Figure 10).

It appears that the characteristics or input impedance of the symmetrical resolver is about equal to the image impedance of the 8-A-1 resolver. These two facts show that there is surprisingly little difference in performance between the symmetrical resolver and the particular step-down resolver selected for analysis.

Also evident from the plots is that the approximate formulas for large n, or $n >> 1$, appear valid in all cases for $n \geqq 3$. These formulas are 1a and 2a for the iterative connection, and 8b, 9a and 10a for

FIG. 9

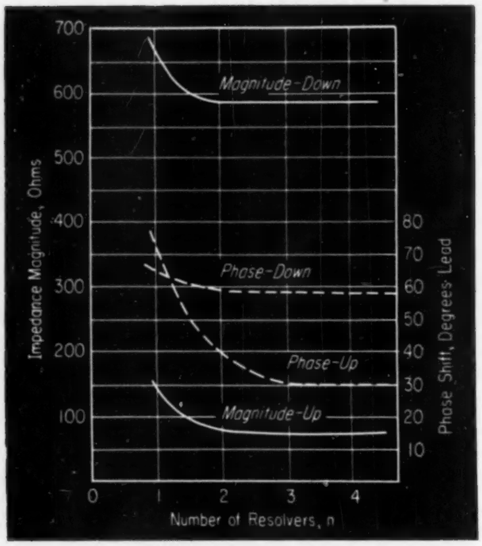


FIG. 11

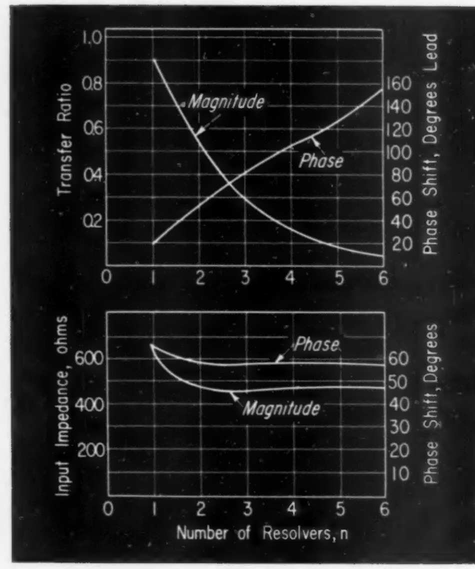


FIG. 10

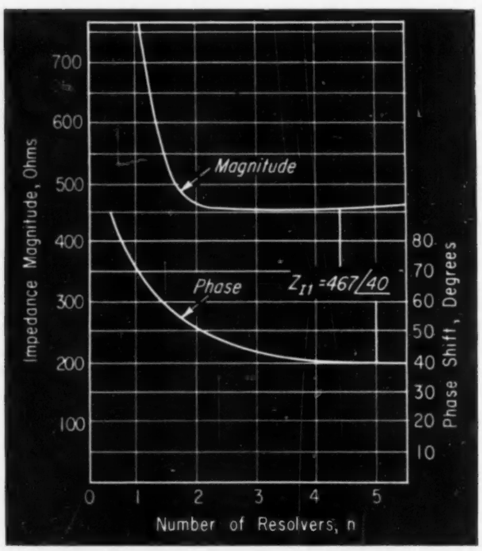


FIG. 9. Comparison of magnitude and phase shift of the input impedance for one to five resolvers in the two iterative (up and down) connections.

FIG. 10. Input impedance characteristics for one to five resolvers in the image connection (compare with Figure 9).

FIG. 11. Transfer ratio and input impedance for one to six symmetrical resolvers in cascade (compare with Figures 9 and 10).

the image connection. This validity is because the error term is of the order of $e^{-2n\lambda}$ or $e^{-2n\theta}$. For $n = 3$, and for the resolver considered, this term has a maximum value of about $(0.5)^6 \cong 0.016$, which is negligible compared to unity.

Application to rotary transformers

The theory developed here may be applied directly to chains of other passive elements, especially rotary (linear) transformers. However, two complications arise in this connection:

1. The output impedance and equivalent-T circuit for a typical transformer varies noticeably and must be evaluated for each shaft position.
2. The linearity of this unit, considered as a voltage generator driving a load $Z\angle\phi$, is affected by its varying output impedance. Hence Thevenin's equivalent circuit should be used instead of the T-circuit to calculate linearity errors under load.

The experimental work referred to in this article was done by Stewart Weisberg of the Norden Laboratories Div.

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Guide to EQUIPMENT COSTS for Industrial Pressure Measurement

HOWARD R. KALBFLEISCH, New Hyde Park, N. Y.

Data File No. 9 (CONTROL ENGINEERING, OCT. '57) presented a series of tables for determining initial equipment costs for a variety of temperature-measuring systems. The following tables, prepared by the same author, provide a complementary guide to pressure-measuring systems.

Again factors such as range and accuracy of the instruments, type of sensing element, and system functions affect proper selection. Since more than one arrangement may satisfy requirements of a particular system, it is important to select the one that best suits the problem and is the most economical.

Table 1 shows the working range of some common pressure-sensing elements, and Table 2 covers the cost of various instrument arrangements and control loops. Figures shown are based on direct-connected, pneumatic, and electronic systems. Table 2 also relates cost to the type of element used and the expected accuracy. Numbers under the cost figures refer to the diagrams shown in Table 3. These diagrams illustrate the instruments and control components included in the cost of the corresponding system.

FOLLOW THESE STEPS

► Select in Table 2, columns A and B, the pressure range desired and the type of sensing element to be used.

► Note in column C the expected accuracy of each alternative, and choose the one most suitable for the application.

► Move across the table to column D. Under the desired instrument function or control loop, find the equipment cost and corresponding diagram number.

If the arrangement selected in this way is not satisfactory in cost, accuracy, sensing element, or type of system, then move to the right or left, up or down, to select a more appropriate one.

COSTING GROUND RULES

System costs shown in Table 2 reflect high-quality components. Additional features such as alarm contacts will, of course, increase these costs. The example below Table 3 demonstrates how the total cost figure was obtained for the 0 to 20,000-psig, helical-operated, pressure-indicating controller (diagram 15 in Table 3). Prices used are as of December 1957.

The costs in Table 2 cover the following:

- Normal pressure measurement service.
- Single-point, panel-mounted recorders and controllers of the miniature type with electrical chart drives. (Direct-connected indicators costing \$17 and \$24 are 4½-in. pressure gages.)
- High-quality air or electrically-operated 1-in. valves.
- Wiring or plastic tubing between sensing element or transmitter and instrument panel (100 ft, except element F, which is 60 ft) and between panel and valve (100 ft).
- Outlet box or air set for connection to electrical power lines or air supply.

Costs do NOT cover:

- Installation or operation
- Explosion-proofing
- Special calibration or materials

When measuring vacuum below 10^{-3} mm Hg, accuracy is a problem unless the gas being handled is known. If it is not, the user should get advice from the gage manufacturer.

Table 1 RANGES FOR PRESSURE-SENSING ELEMENTS

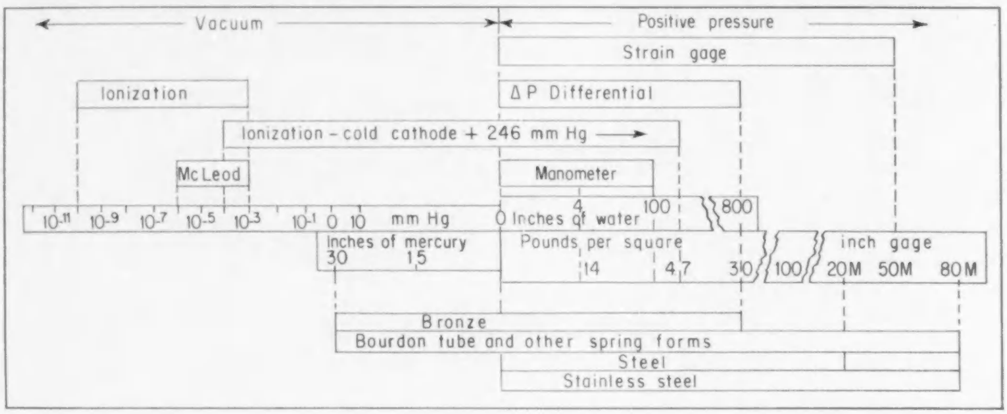


Table 2 TYPICAL SYSTEM COSTS

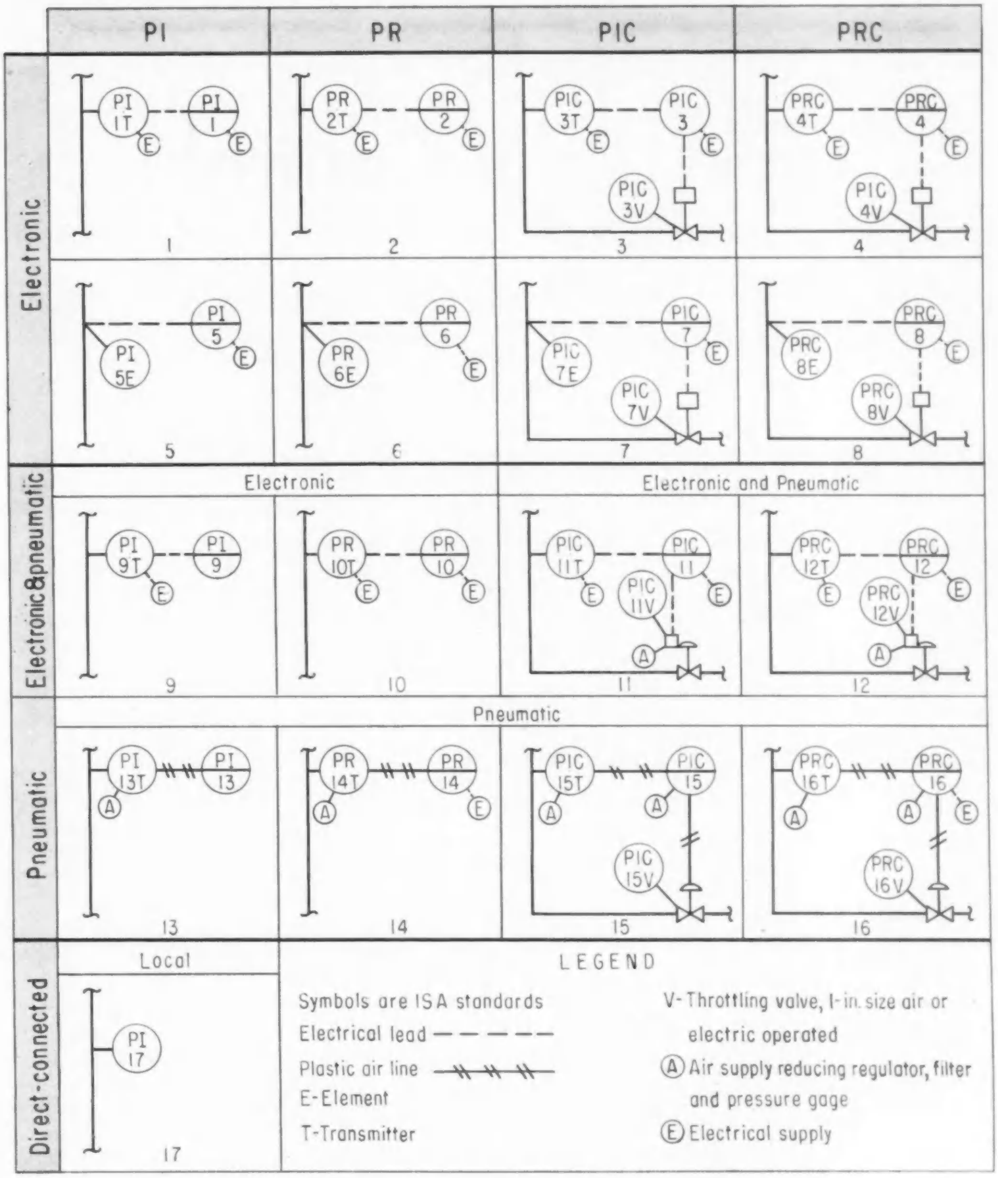
A		B		C	D				
Range		System		*Limits of error		Instrument function or loop			
Low	High		Element			PI	PR	PIC	PRC
10^{-4} mm Hg	1000 or +246 mm Hg	Electronic	** Ionization tube	Depends on installation About ±2%	$	610	1,260		
					Diag.	5	6		
10^{-10} mm Hg	1 mm Hg	Electronic	Ionization tube	Depends on installation	$	575	1,225		
					Diag.	5	6		
0 psig	20,000 psig	Electronic	Strain gage	¼% or better	$	540	580	1,175	1,170
					Diag.	5	6	7	8
ΔP 0 in. water	800 in. water	Electronic & pneumatic	Diff. press. cell	1%	$	475	640	1,220	1,310
					Diag.	9	10	11	12
0 psig	20,000 psig	Electronic & pneumatic	Strain gage	¼% or better	$	540	580	1,100	1,190
					Diag.	5	6	11	12
30 in. Hg vac	15 psig	Electronic & pneumatic	Bronze diaphragm	½ to 1%	$	340	515	1,095	1,185
					Diag.	9	10	11	12
ΔP 0 in. water	800 in. water	Pneumatic	Diff. press. cell	½ to 1%	$	325	490	875	1,005
					Diag.	13	14	15	16
0 psig	20,000 psig	Pneumatic	Helical 316 s.s.	½ to 1%	$	195	360	745	875
					Diag.	13	14	15	16
30 in. Hg vac	15 psig	Pneumatic	Bronze diaphragm	½ to 1%	$	190	355	740	870
					Diag.	13	14	15	16
10^{-6} mm Hg	10^{-3} mm Hg	Direct connected	Mc Leod Hg tube	±1%	$	120 to 300			
					Diag.	17			
0 in. water	100 in. water	Direct connected	Glass well manometer	About 0.1 in. manometer liquid	$	98			
					Diag.	17			
0 in. water	4 in. water	Direct connected	Inclined glass well manometer	About 0.01 in. manometer liquid	$	46			
					Diag.	17			
0 psig	20,000 psig	Direct connected	Cr. mo. steel bourdon	½ to 1%	$	24			
30 in. Hg vac	0 psig				Diag.	17			
0 psig	1000 psig	Direct connected	Bronze bourdon	½ to 1%	$	17			
30 in. Hg vac	0 psig				Diag.	17			

* Limits of error are shown as % of total instrument range.

** Distance from tube to panel instrument is 60 ft.

Refer to Table 3 for corresponding diagrams.

Table 3 ELEMENTS AND CIRCUITS



COSTING EXAMPLE

The cost of a 0-20,000 psig helical-operated (PIC) pressure-indicating-controller (Diagram 15) is $745; the breakdown follows:

Transmitter, pneumatic	$140
1 point indicator, automatic-manual	220
Plug-in-controller, throttling and reset	150
Ring air-operated diaphragm valve	187
2 air sets, reducing regulator and filter	28
200 ft plastic tubing	20
Total	$745

Applying Pneumatic Relays to Industrial Control

PART II—SEVEN USES FOR MULTIFUNCTION RELAYS:

- *MEASURING SOLIDS WEIGHT IN HOPPERS*
- *CONTROLLING WEIGHT OF BELT-CONVEYED SOLIDS*
- *COMPENSATING MACHINING DIMENSIONS*
- *CONTROLLING PRODUCT PURITY FROM PROCESS MEASUREMENTS*
- *CONTROLLING OVERPEAKING DURING START-UP*
- *CONTROLLING ENERGY BALANCES*
- *CONTROLLING WINDING SPEED AND TENSION*

H. SHERID GARRETT, Moore Products Co.

In many control applications multiple input signals, or modifications of signals, are used to obtain a specific control characteristic. Often multifunction pneumatic relays can provide this characteristic. The two basic multifunction relays are the pneumatic-force-balance relay and the mechanical-force-balance relay. Although their constructions differ—and construction has some effect on performance—either relay can be used in the applications to be described in the following pages. Because of their versatility in solving a variety of practical static and dynamic problems, multifunction relays are considered to be pneumatic computers.

The term force balance means that all unbalancing forces due to pressure signals in the relay's chambers must be canceled out before the output pressure can assume any constant value. In both types of relays chambers *A* and *B* apply a positive force—an increase in pressure in either chamber results in an increase in output pressure *D*—and chambers *C* and *D* apply a negative force. Springs provide an adjustable positive or negative mechanical bias force that adds to or subtracts from the air signals. To assure this condition, supply pressure *S* must be greater than maximum output pressure.

The pneumatic force balance relay, at the top of the next page, responds to pressure applied to its equal-effective-area input chambers and to spring loading. Pressure in chamber *A* is exposed to a unit-area diaphragm, pressure in chamber *B* to two diaphragms: the upper one has the same unit area as chamber *A* and produces a unit negative force, and the lower one has two unit areas and produces two units of positive force. The resultant force in chamber *B* is one positive unit. A given pressure change in chamber *A* or *B* will produce the same output pressure change.

Chamber *C* is constructed similar to chamber *B*, and chamber *D* is similar to chamber *A*, but the resultant forces in *C* and *D* are negative. Pressure in *D* is the relay's output pressure.

The mechanical force balance relay, below the pneumatic relay, responds to pressures applied to equal-area input chambers, to spring loading, and to the lever ratio L_1/L_2 determined by the adjustable fulcrum. The basic relationship for *D* is:

$$D = L_1/L_2(A - C) + B \pm K$$

This equation applies to the pneumatic force balance relay, too, when the L_1/L_2 ratio is provided by feeding back, through a pressure-dividing circuit of two orifices in series, from output *D* to *A*.

Functions obtained from the basic equation also apply to both types of relays. When the lever ratio is unity, $D = A + B - C \pm K$. The average of two signals applied to chambers A and B can then be obtained by connecting the output D back to chamber C, so that C equals D. The equation, with this circuit, becomes:

$$D = (A + B)/2 \pm K$$

Reversing action can be obtained for one input signal. In this case C is the input and the output is:

$$D = K - C$$

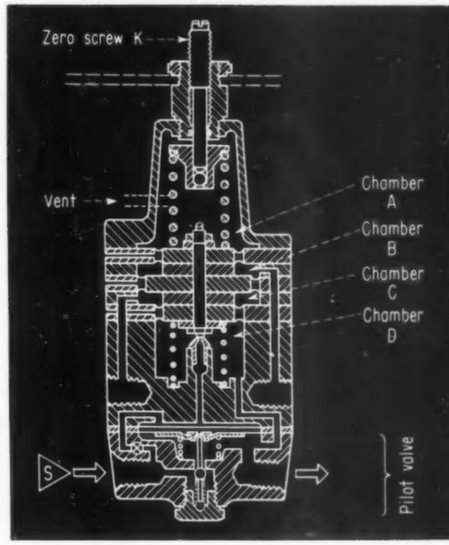
Multiplication of one input by a constant can be obtained by adjusting the lever ratio to equal the constant. Thus, with A as the only input and with B and C not connected to signals, the output is:

$$D = L_1/L_2A \pm K$$

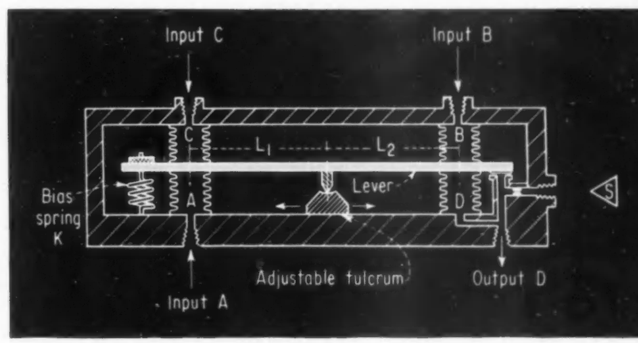
The basic arithmetic relationship permits calculations of many other static characteristics.

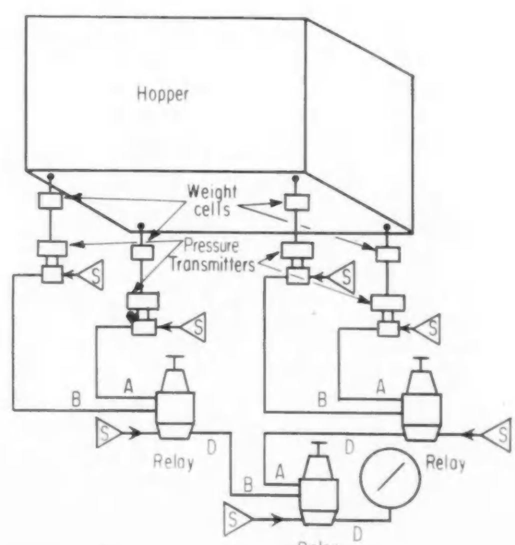
Adjustable orifices (needle valves) in the inputs and output extend the versatility of multifunction relays so that they provide dynamic characteristics involving a time element. Pulsing, one such characteristic, is used in an application that follows. Proportional plus reset, also used in an application, is another example. Here, pneumatic set-point is applied to chamber A and the measurement signal from the transmitter is applied to C. The reset action is obtained by connecting output D through an adjustable orifice to chamber B. The ratio L_1/L_2 provides the proportional action. As long as any offset or deviation persists between set-point and measured signals (any pressure difference in chambers A and C), the output pressure will continuously change because of the continuous feedback from the output into chamber B. The adjustable orifice determines the reset rate.

Pneumatic force balance relay



Mechanical force balance relay

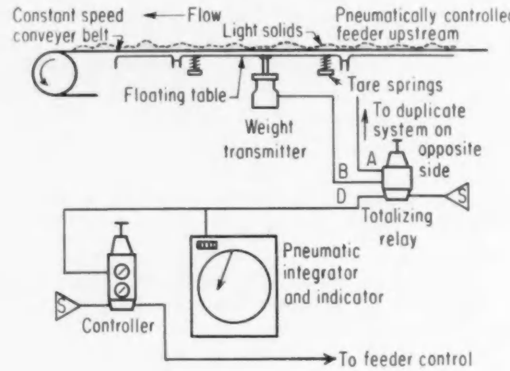




Measuring solids weight in hoppers

A typical solids weight measurement problem and its solution is shown at the left. Solids can be weighed in a hopper of square cross-section with four load cells, one in each corner. Regardless of the distribution of the material in the hopper, the four transmitters measure the total load. Three multifunction totalizing relays add the four weight signals. Two signals are fed to and added by one relay, the other two by the second relay. Then both outputs are fed to a third totalizing relay whose output is the total weight of solids in the hopper.

Controlling weight of belt-conveyed solids

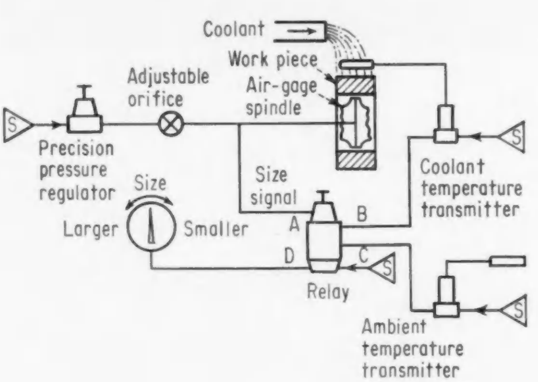


At the right is an arrangement for measuring the weight of solids dropped onto a moving conveyor belt. The floating-table weighing mechanism supports the belt from underneath and two weight transmitters—one on each side of the table—detect a portion of the total load. The system measures the total load, even though the solids may not be distributed evenly on the belt, as the solids come from the pneumatically controlled upstream feeder.

Each transmitter will have maximum output with maximum load. If all product is on one side of the belt, the transmitter output on that side will represent the total net weight, the other transmitter a zero weight. If the load is distributed 30 and 70 percent about the belt's centerline, the transmitter outputs will correspondingly be 30 and 70 percent of maximum. The pneumatic output signals from the weight transmitters go to a multifunction totalizing relay whose output is the sum of the two signals representing the solids' weight. Totalizing-relay output goes to the feeder upstream to correct any deviations in the desired weight.

Since the conveyor belt moves at constant speed, this weighing system actually controls the product's flow rate. Thus the belt output can be rated in such terms as lb per min or tons per hr. An elaboration of this weighing technique will permit accurate proportioning of two or more solids while maintaining the preset production rate of the blend.

Compensating machining dimensions



The small tolerances, on the order of plus or minus 0.0001 in., permitted in modern machining practice require dimension-measurement correction for ambient and liquid-coolant temperatures. Otherwise, the machining error due to these factors would be too large a percentage of the tolerance. In other words, fluid-coolant or ambient temperatures influence the part size, and the size will be in error at the basic temperature at which the part will be used.

The diagram above shows how a multifunction relay can compensate the dimension measurement for these temperatures. Basically, a pneumatic dimension-transmitter measures the size of machined or formed parts and transmits an air signal proportional to exact size to a size-control circuit. The size control responds to dimension changes as small as 0.000005 in. The closed loop is completed by controlling the machine or tool responsible for the dimension being measured.

The figure shows the dimension transmitter measuring the inside diameter of a cylinder. This dimension is exactly reproduced by a multifunction relay if there is no correction. Measurement is corrected by adjusting the relay output with a pneumatic signal, proportional to coolant and ambient temperatures and in accordance with the difference between the actual temperature and basic temperature at which the exact dimension is desired.

Suppose the coolant temperature—which affects the workpiece—is higher than the basic temperature; then the ID of the part will be enlarged. But if the part is machined without any correction, the ID will be too small at the basic temperature. The coolant temperature therefore adds to the relay output, and more material is removed at the higher temperature. The result is a part machined at one temperature to be exactly dimensioned at another (the basic) temperature.

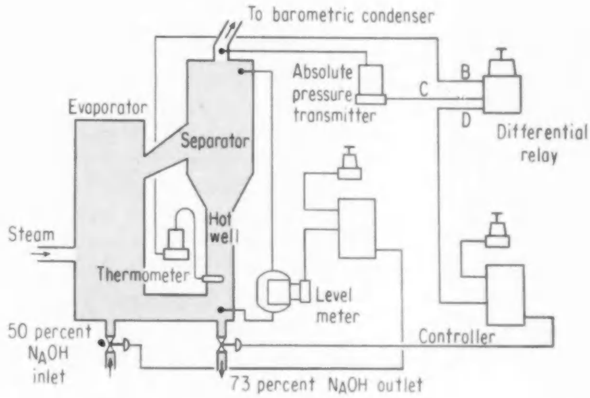
A similar analysis may be made for ambient temperature correction because the measuring element itself changes size with temperature. An ambient temperature larger than basic would result in an erroneous measurement, making the part too small.

Controlling product purity from process measurements

In such processing units as evaporators and distillation columns there is a correlation between product purity and temperature and pressure. Meeting product quality specifications can be accomplished if this relationship can be instrumented and used for control. An interesting example of relation control is in a caustic evaporator (next column), where it is used to obtain desired 73 percent sodium hydroxide ($NaOH$) caustic products from 50 percent $NaOH$ feed stream. The stream heats the stream and boils off water to increase product concentration. The solution concentration remaining in the hotwell is a function of the solution's pressure and temperature, or boiling point. At a certain pressure and temperature a certain amount of water vapor will pass off from the 50-percent solution, leaving a solution whose boiling point corresponds to that pressure and temperature.

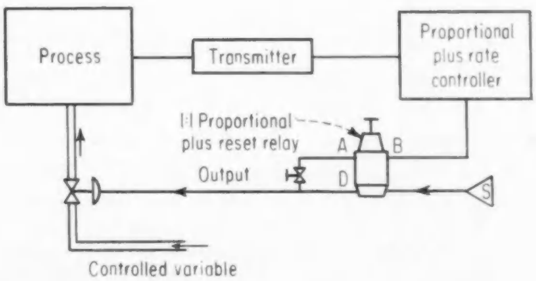
Many combinations of pressure and temperature make up the boiling point curve for 73-percent solution, while still other combinations make up other solution percentages. Generally, the boiling point curve is nonlinear, but over a limited range it can be considered linear. In this linear range, the temperature transmitter is calibrated to transmit the same pneumatic output range as the pressure transmitter does for the pressure range. The thermometer output will always equal the pressure transmitter output when the concentration is 73 percent.

The signals are connected to a multifunction pneumatic relay, which measures the difference between them. Thus, the relay output will equal only the relay spring loading when the concentration is 73 percent. The relay output is compared with the controller set-point. The spring loading and the set-point usually are fixed at 9 psi at the desired concentration. With this arrangement, a difference between the pressure and temperature signals produces an error at the controller which develops a correcting signal to adjust the outlet flow valve. Specifically, if the concentration decreases from 73 percent to 65 percent the valve closes proportionally and holds the product in the evaporator for a longer time, during which time the steam boils off more water and increases concentration back to the set-point. Although this control method assures a quality product, it does so at the expense of a variable production rate. A liquid-level control circuit maintains the level of the 50-percent $NaOH$ feed, compensating for changes in production rate by controlling the inlet valve.



Controlling overpeaking during startup

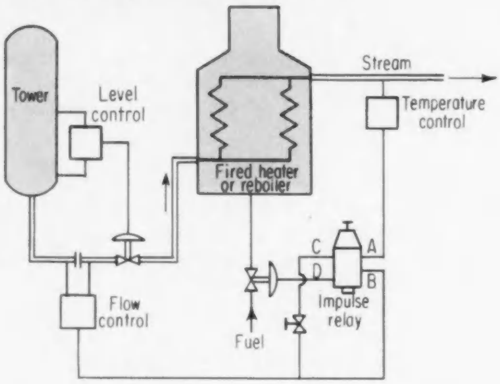
The common practice in modern three-mode stack-type controllers of introducing the rate mode before the reset mode eliminates overpeaking during process startup. Most older-style case-type controllers cannot be internally modified in existing installations to provide nonoverpeaking, but many of them already do have proportional and rate action, so that nonoverpeaking requires only 1:1 proportional plus reset action following the controller. This arrangement is shown at the left.



A multifunction pneumatic relay provides 1:1 proportional action through its 1:1 diaphragm ratio (or lever ratio, in the case of a mechanical force balance relay). The controller signal is applied to chamber *B*. The reset action is obtained by connecting output *D* through an adjustable orifice to chamber *A*. The adjustable orifice (needle valve) determines the rate of output change or reset time.

The reset mode will thus be actuated from the lead factor of the rate mode, which permits the reset mode to correct itself just as the process reaches the set-point. The reset and valve values and proportional band may be set in accordance with any of the formulas found in the literature.

Controlling energy balance



An important use of multifunction pneumatic relays is keeping in balance those energies that affect a variable. A typical case is shown above. Here product temperature at the outlet of the fired-heater controls heater fuel flow, hence heat input to the process. Changes in liquid level in the tower or in the product flow rate will have an effect on the temperature, but the effect will be delayed due to time lag in the process. For an increase in product flow rate, for example, means that a preset fuel rate must now heat more product in the same time and the product temperature must decrease. However, several minutes may elapse before this decreased temperature is sensed by the temperature controller and a correction made to the fuel-control valve to increase fuel-flow rate. Poor control exists during this time.

A multifunction relay, modified and connected to produce correcting impulses, improves controllability. The basic relay, pneumatic or mechanical, is modified by an adjustable needle valve (adjustable orifice) connected between chambers *B* and *C*. It receives two signals, a primary from the temperature controller and a secondary from the tower-effluent flow transmitter. The relay output, chamber *D*, totalizes the inputs and adjusts the fuel valve.

During steady product-flow conditions the pressures in chambers *B* and *C* are equal, thus canceling each other out so that the relay output is controlled only by the temperature signal in chamber *A*. However, when a flow change occurs its full signal appears immediately in chamber *B* but builds up slowly in chamber *C* because of the restriction. Thus, a flow-signal pulse at *B* is added to the steady temperature signal at *A*, and the relay output adjusts fuel rate for both temperature and flow. The temperature starts to correct immediately.

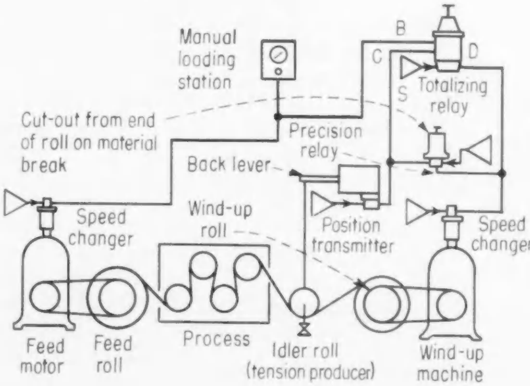
Some time after the flow stops changing the flow-signal pulse is canceled out because the pressure in chamber *C* has reached that of chamber *B*. The canceling time is adjusted at the needle valve so that cancelation is completed just when the level or flow change reaches the temperature controller. Then the temperature signal alone adjusts the fuel valve, through the multifunction relay.

Controlling winding speed and tension

One big problem in the winding of continuous sheet material is speed synchronization of feed and wind-up machines. Basic synchronizing may be done by sending one speed-control signal from the manual loading station to both feed and wind-up mechanisms, as shown at the right. However, to take care of individual wind-up characteristics and such variables as load changes, tension changes, drying time, and roll size changes, additional speed-trimming adjustment is necessary on the wind-up machine. The variables are usually adjusted through an idler roll, with a pneumatic position transmitter forming and maintaining a slack loop.

Idler-roll position signal is fed immediately to the wind-up machine speed control along with the basic speed signal. Thus, a position change is detected and corrective action is completed rapidly enough, even on fast-moving sheet material, to prevent loosening or tightening of the loop and consequent tearing or dragging of the material. A multifunction pneumatic relay totals the basic-speed and trimming signals. The output of this relay represents the proper speed signal corrected for all loop variations.

The high-gain precision relay in the circuit is a safety feature. Should the material break or reach the end of the roll, the idler roll moves to a limit and produces a pneumatic signal that shuts down the wind-up machine. A modification of the circuit will allow shutdown of the feed machine, too.



Positioning Systems - III

JOHN D. COONEY and BYRON K. LEDGERWOOD, Control Engineering

This is the third and concluding part of Control Engineering's staff-researched report on 31 different foreign and domestic design approaches to numerically controlled point-to-point positioning systems. Included are descriptions of nine systems with full coverage of performance characteristics and their modes of operation.

CHECKLIST OF SYSTEM CHARACTERISTICS-III

MANUFACTURER	COST	EQUIPMENT FURNISHED	ACCURACY	AVERAGE POSITIONING TIME OR SPEED BETWEEN POINTS	STORAGE MEDIA	STORAGE CODE	TYPE OF MEASURING SYSTEM
MODERN ENGINEERING SERVICE CO. 1695 Twelve Mile Road Berkley, Michigan *no.* 23	\$9,500	One-axis programmer with mobile console, manual input and electrical control panel, but without tape reader	± 8 sec of arc	6 sec for 30-deg index	Standard 1-in., 8-channel punched tape	Binary-coded decimal	Pulse generator geared to table motion (incremental)
REEVES INSTRUMENT CORP. 215 E. 91st St. New York, N. Y. *no.* 24	—	Control system complete with console, feedback devices, tape reader and power servos	± 0.0002 in.	1-5 sec	6-channel, 1-in. punched tape	Binary-coded decimal	Precision potentiometers and resolvers geared to rack and pinion (absolute)
NATIONAL AUTOMATIC TOOL CO., INC. Richmond, Indiana *no.* 25	—	Machine tools and positioning tables complete with all necessary controls and tape reader	± 0.002 in.; repeatability ± 0.0002 in.	150 in. per min (rapid traverse)	Standard 1-in., 8-channel punched tape	Decimal	Decimal-coded discs (absolute)
WESTINGHOUSE ELECTRIC CORP. SYSTEMS CONTROL DEPARTMENT Buffalo, N. Y. *no.* 26	\$4,000 to \$15,000 per axis depending on length and accuracy	Complete multi-axis control consisting of reader, feedback elements, control station, power servo plus transistorized circuitry	To ± 0.0001 in. per ft standard; to ± 0.0001 inch total with calibration	200 in. per min	Standard 1-in., 8-channel tape; punched cards; selector switches	Binary-coded decimal for tape; decimal for cards	Linear synchros in stepless switching arrangement and/or "Nultrax" transducer (absolute)
ELECTROSYSTEMS, INC. 2741 North Naomi Street Burbank, Calif. *no.* 27	\$7,000 per axis	Positioning table complete with control console, tape reader and drive servos	± 0.001 in.	100 in. per min (rapid traverse)	Special 10-in. Mylar tape or standard 1-in. tape	Binary-coded decimal	Decimal-coded disc-type converters (absolute)
NORDEN-KETAY CORP. 13210 Crenshaw Blvd. Gardena, Calif. *no.* 28	\$6,000 to \$30,000	Will supply complete system for use on new or retrofit equipment	± 0.001 in.	360 in. per min (maximum slow speed)	Standard 1-in., 8-channel punched tape	Binary-coded decimal	Coded discs (absolute)
WARNER & SWASEY RESEARCH CORP. 34 West 33rd St. New York 1, N. Y. *no.* 29	\$9,950	Two-axis control, measuring units, control console and tape reader, but without positioning motors	± 0.0001 in.	100 in. per min (rapid traverse)	Standard 1-in., 8-channel punched tape	Binary-coded decimal	Coded discs (absolute)
EKCO ELECTRONICS, LTD. Southend-On-Sea, Essex England *no.* 30	—	Complete control system including panelboard, feedback transducers and power servos	± 0.0002 in.; ± 7 sec of arc	24 in. per min	Calibrated dials; punched cards	Decimal	High- and low-resolution pots plus 3-decade mechanical counter (absolute)
CLEVELAND INSTRUMENT CO., INC. 735 Carnegie Ave. Cleveland 15, Ohio *no.* 31	\$15,000	Rotary positioning system complete with transducers, card reader, and power servos, but without table	± 3 sec of arc or ± 0.0001 in.	10 sec; 1.5 rpm on rotary table	Rem Rand punched cards; Standard 1-in., 8-channel punched tape	Decimal on cards; binary-coded decimal on tape	Wire-wound pot for coarse positioning plus differential-transformer vernier (absolute)

REPRINTS AVAILABLE

Complete Series (Parts I, II & III)—\$1.25

Part I—60¢; Part II—50¢; Part III—40¢

Write Readers Service, Control Engineering, 330 W. 42 St., N. Y. 36, N. Y.

System

23

MODERN ENGINEERING SERVICE CO.

FIG. 23.1. JACY precision index and pierce machine. Part shown is a jet-engine turbine stator band with 56 airfoil slots. Time to index and pierce one slot is about 8 sec.

Although theoretically applicable to linear positioning, the Type II control system has to-date been used exclusively on rotary tables. Modern Engineering Service Co. of Berkeley, Mich. supplies the control separately, as part of complete positioning tables in 18-, 24-, 36-, and 45-in. diameters, or installed on a JACY piercing machine, Figure 23.1. Cost of a 45-in. table is about $33,000, including complete electrical controls and control panel, programmer, electric motor, hydraulic fluid motor, and automatic lubrication systems. The programmer alone is priced at $9,500 with mobile console, pushbuttons for manual input and electrical control panel, but without tape reader.

Tape-controlled systems employing Flexowriter equipment arranged for binary-coded decimal storage are obtainable. Reading is done a line at a time into relay-matrix buffer storage. The internal language of the programmer is conventional decimal, so conversion circuits are incorporated. The measuring system consists of a proximity switch feeding pulses to electronic counters. Mechanical resolution is 1 min of arc, with accuracy of plus or minus 8 sec and repeatability of plus or minus 1 sec. The average time required to travel from point to point on a typical 30-deg index is approximately 6 sec. The additional time needed to lock up, pierce and initiate a new index is about 2 sec in the machine pictured in Figure 23.1.

Indexing drive

Rotary movement of the worktable is accomplished through a worm wheel integral with the table, and a worm driven by a hydraulic or electric motor. To minimize backlash, dual leads are cut and ground into worm wheel and worm, respectively. The worm has a low helix angle so that when the drive is stopped the table is effectively locked. The input to the worm gear shaft is equipped with a quadruple lobe master index plate which makes one complete revolution for each 4 min of table rotation. A proximity-type transducer mounted adjacent to the master index plate is triggered each time one of the lobes passes it. In this way, a pulse is delivered to the counting circuits for each 90 deg of index plate movement, equivalent to 1 min of table rotation. For one complete revolution of the table, the transducer dispatches a total of 21,600 (360 x 60) pulses to the counter.

To provide capacity for 21,600 min, a five-decade electronic counter is employed. Each decade consists of a Burroughs beam-switching tube with an associated numerical indicating tube (Nixie) for visual readout. The counter is of the "predetermined" type, meaning that it can be set to react to any given total. When it is desired to turn the table to a given position, the numerical designation of that position (in minutes of arc) is keyed into each decade. This number is then read into the system to set the predetermined counter. Table movement starts, releasing a train of pulses that begin to reset the counter back to zero. When all decades of the counter have been cleared, the table will have been rotated to set-point.

System operation

The master index plate, seen in the schematic block diagram, Figure 23.2, is geared to the table motion. At the start of an index, the table is accelerated to maximum velocity by the electric or hydraulic prime mover. The transducer is excited by a continuous signal from an oscillator. As each lobe of the index plate nears the transducer, its impedance increases to momentarily block the signal. These interruptions are recognizable as pulses, which are amplified and fed to a pulse input control unit. Here the pulses are reshaped, then fed through an input gate to the first of the five predetermined minute counters. These are cascaded to record units, tens, hundreds, thousands and tens of thousands of minutes.

Maximum table velocity is sustained until some quantity X of pulses before zero is reached. Here the counter closes a relay to shift the table to slow speed. The deceleration count is established by means of selector switches on the basis of speed, size, and type of table being controlled and the nature of the drive (whether electric or hydraulic). At one count before zero, a second relay is closed to energize the solenoid of a directional valve. This admits oil to a hydraulic cylinder, which actuates the shot pin or detent that locks up the table.

Irrational indices

In working on circular parts, it is frequently desired to perform some operation at equally-spaced intervals around the part. The JACY control is easily programmed for such repetitive positioning. For example, it may be required to index a part progressively so as to drill a total of 60 identically spaced holes around its periphery. To do this the number 360 (21,600 divided by 60) is set into the predetermined minutes counter. The positioner will then move the table through a series of 360-min steps, with the counter being reset

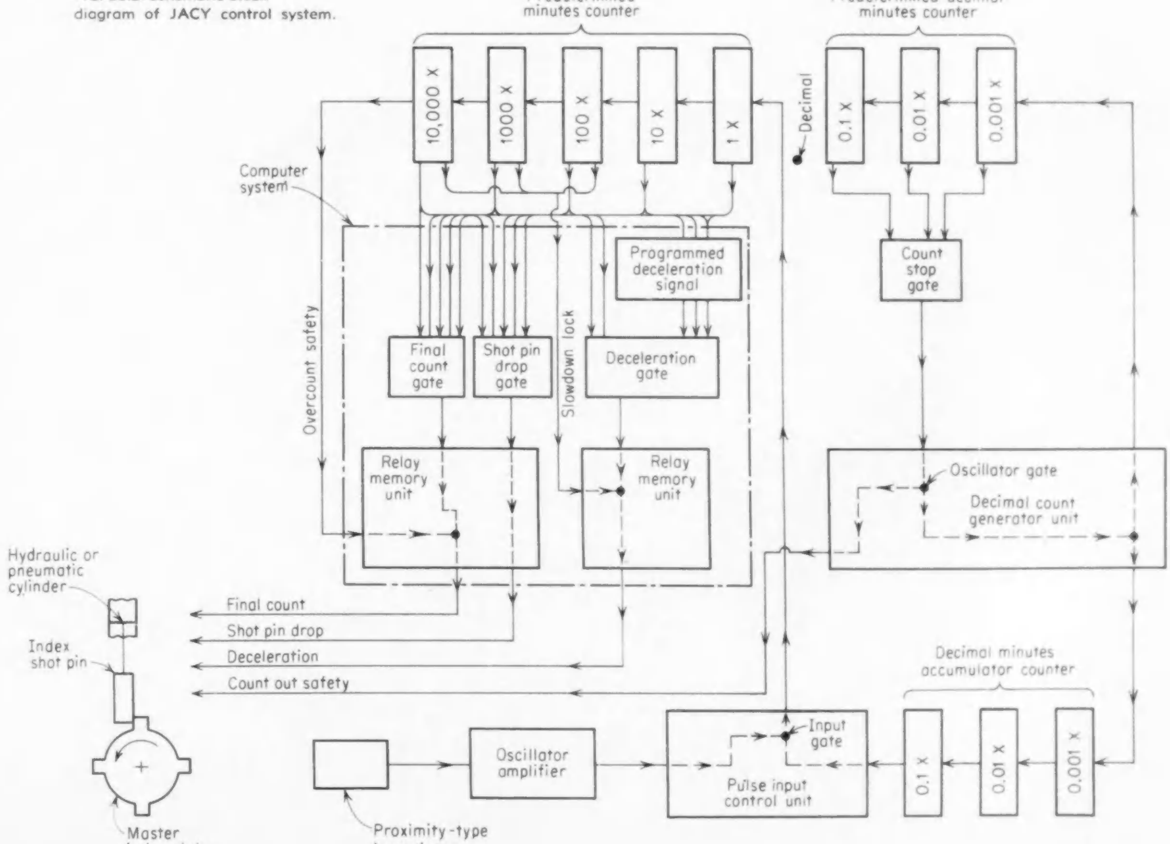
automatically to 360 each time the table steps through an index.

The control problem becomes more complex when irrational increments are involved. To illustrate this, assume that the number of increments desired is 66. The counter setting now must be 327.273, a figure that cannot be handled by the predetermined minutes counter alone. Yet, if the three least significant figures are neglected, there will be a cumulative error of 0.273 x 66 min after the table has stepped through 66 indices. To solve this problem, an additional three-decade counter is provided to handle the three digits to the right of the decimal point. On the very first index, the table is shifted by an increment of 327 min and the remainder (0.273) is stored in an accumulator. This storage function is repeated at each step.

Besides serving as a memory, the accumulator acts to adjust the count in the predetermined minutes counter as the total of the stored remainders mounts. This is done by dispatching an additional pulse to the minutes counter each time the accumulator total passes 0.500. Thus during the second index of the example chosen the accumulator total reaches 0.546 and one pulse is added to the minutes counter. On successive indices, the accumulator total reaches 0.819, 0.092 (since the accumulator range is only zero to 0.999), 0.365, and 0.638. At the last figure, another pulse is generated. By such continuous correction, the position error is never more than 38 sec. Such irrational increments occur with a varied program of tape inputs as well as with the repetitive situation chosen in this example.

Operation of the accumulator circuit is as follows: at the beginning of an index the reset signal permits a free-running multivibrator to transmit signals into an oscillator gate and then through dual amplifiers. These signals are fed simultaneously to the predetermined decimal minutes counter decades and to the decimal minutes accumulator decades. The pulse flow is permitted until a predetermined count in the decimal counter triggers a count stop gate; then it feeds back through a cathode follower and count-stop memory to close the oscillator gate. At the same time this cuts off the feed of pulses into the accumulator decades. Consequently, at the beginning of each index the accumulator is fed a discrete number of pulses, equivalent to that programmed into the predetermined decimal minutes counters. This enables the accumulator decades to store a progressive total and to direct, as previously explained, an additional pulse to the pulse input control unit for remainders above 0.500. Then, the master index plate will make an additional quarter revolution, tantamount to one extra minute of table movement. The control hardware involved in this function is a carry-over memory in the pulse input control unit which triggers the input gate and drives (through an amplifier) the units decade of minutes counter.

FIG. 23.2. Schematic block diagram of JACY control system.



System

24 REEVES INSTRUMENT CORP.

Reeves markets the Auto-Set control system as a complete package with custom modifications to suit new or existing machines. System hardware, such as programmer units, power servos, and position transducers, are also supplied separately to control builders. Present applications of the Auto-Set positioner include drilling machines, horizontal jig borers, and an automatic component inserter for printed circuit boards.

The input medium is six-channel Flexowriter punched tape which provides sufficient capacity for any number of parity-checked binary-coded decimal digits. Positioning accuracy of plus or minus 0.0002 in. has been obtained with repeatability of plus or minus 0.00005 in. The time needed to travel from point to point depends on the type of servo drive and the positioning accuracy demanded. For a small drill press an average time of 2 to 4 sec was noted.

System operation

A block diagram of the Auto-Set control is given in Figure 24.1. Tape information is read a line at a time and is switched to the X, Y or auxiliary function translators as determined by the address punched. Function of the X and Y position translators is to generate fine and coarse reference voltages that are analogous to the input numbers. These voltages are compared to the outputs of the coarse resistance potentiometer and the fine induction potentiometer, which are shown driven by the machine slide through a rack and pinion. The actual coarse and fine relationships are decided, of course, by the length of the axis and the resolution desired. In the application described in the block diagram the shafts of the resistance potentiometers make 1 rev for 20 in. of slide motion while the shaft of the induction potentiometer turns once for only 4 in. of linear travel.

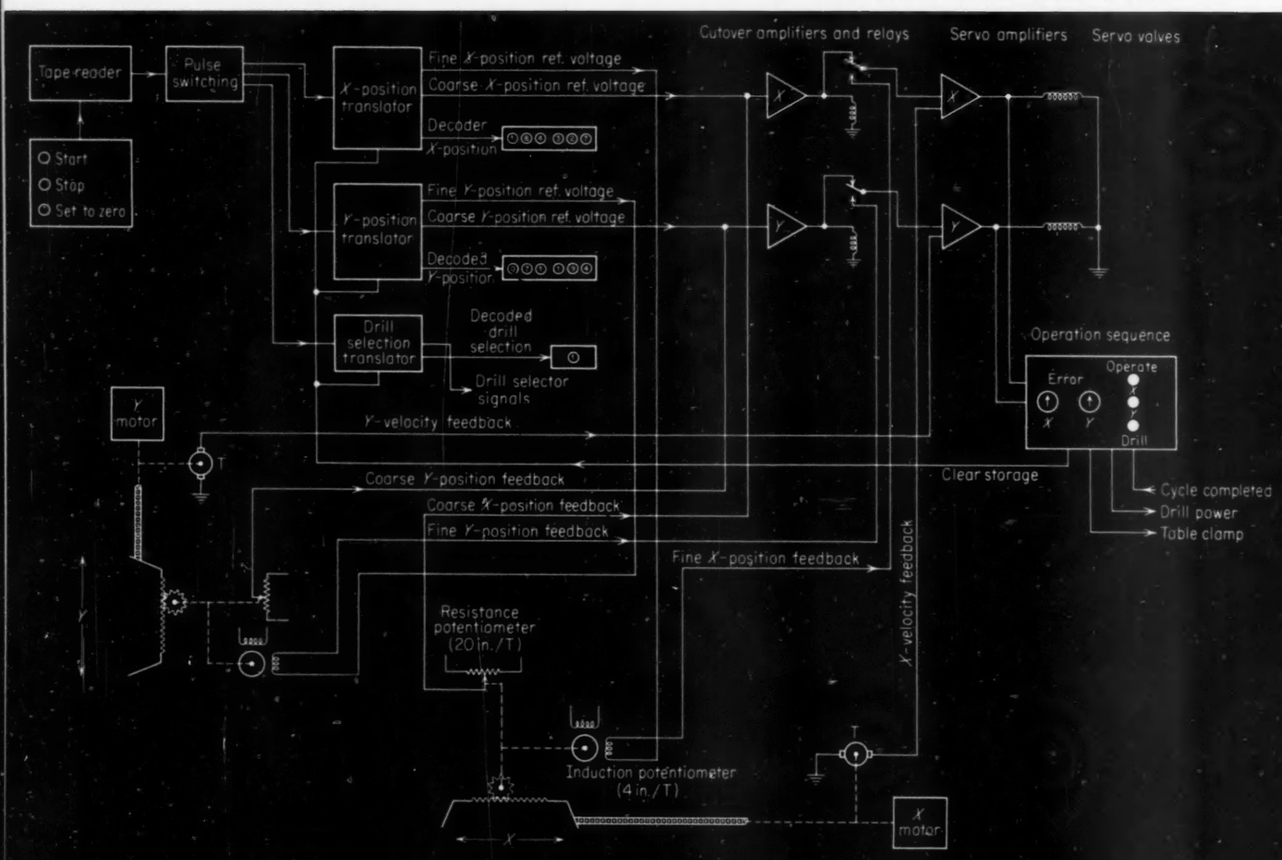
The cutover amplifiers and relays connect the fine and coarse loops individually to the servo amplifiers. The magnitude of the error voltages determine which circuit is made at any given time. After amplification, the error voltages energize servomotors that position the machine in the X and Y axes. The command positions for both X and Y axes are displayed at all times on the console. The display elements are numerical indicating tubes excited from a binary-coded-decimal to decimal conversion matrix in the translators.

Translator action

Figure 24.2 is a schematic diagram of a tape-operated translator unit for one axis. There is one bank of relays for each digit of the position number. A five-digit position number such as 99.999 in. thus requires five relay banks and occupies five rows of the tape. As each row of data is read certain of the relays designated 8, 4, 2, and 1 are energized in conformance with the hole configuration on the tape. By means of a holding circuit (from "relay supply" to ground) the digit is stored while the succeeding rows are interrogated.

The fine error signal is supplied from the upper three

FIG. 24.1. Block diagram of two-axis positioner.



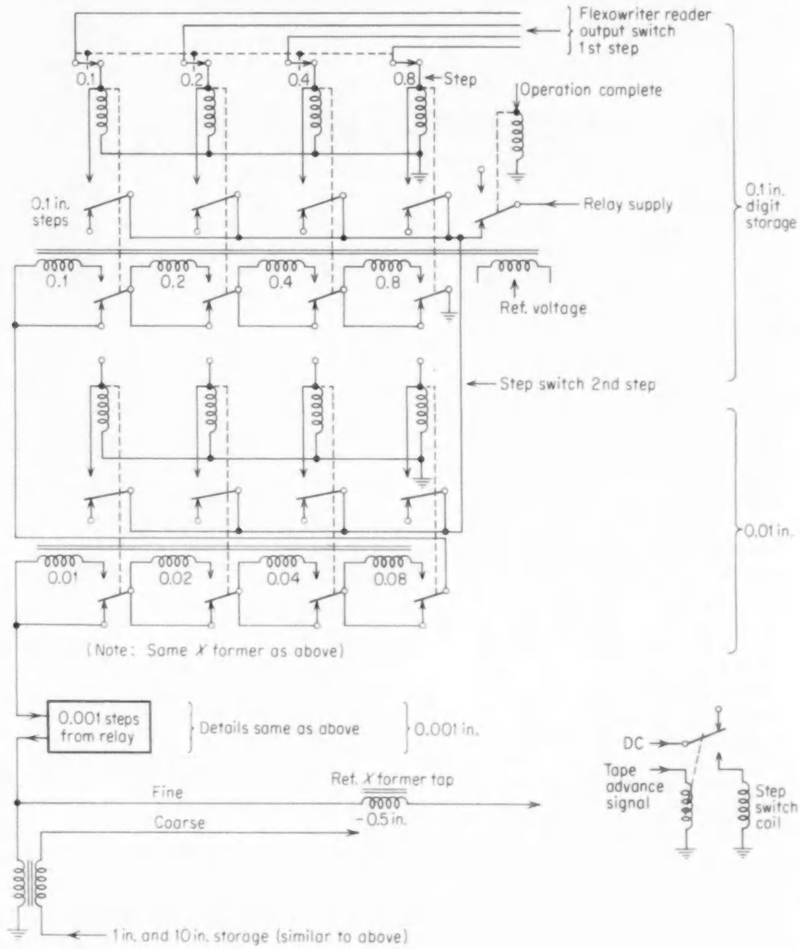
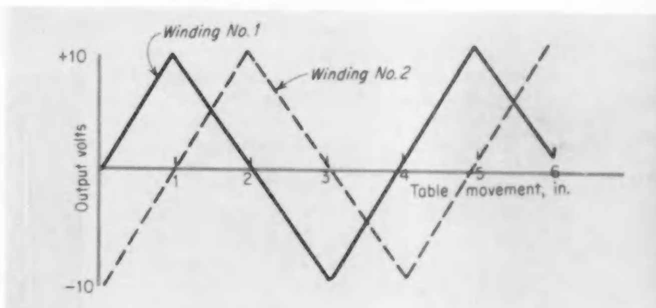


FIG. 24.2. Schematic diagram of translator unit for one axis.

FIG. 24.3. Output voltages of two-winding induction potentiometer.



banks (0.1, 0.01 and 0.001 in.) in Figure 24.2. Two additional groups of relays are assigned to the coarse signal corresponding to the two most significant digits. The source of the fine error signal is a transformer having three groups of isolated secondary windings. The four windings in each group bear an 8-4-2-1 relationship to one another with respect to their number of turns. Thus, by energizing various combinations of relays in the three banks, a summary X voltage is formed that is proportional to the magnitudes of the binary-coded decimals inscribed on the first three rows of the tape.

Each fine transducer is a two-winding induction potentiometer that produces two separate output voltages as the shaft is turned. These voltages have saw-tooth envelopes, one displaced 90 deg from the other. The inherent advantage of this transducer is that it allows a fourfold improvement in resolution.

This is accomplished by using the coarse positioning circuits to switch at any given time just one of the pot windings into the comparison circuitry. Thus, to select a position between 0 to 1 in., winding No. 1 is used, while between 1 and 2 in., winding No. 2 is active. Between 2 and 3 in., winding No. 1 is used again, but with connections reversed to provide a swing from 0 to + 10 volts (rather than from 0 to − 10 volts as shown on the schematic). Similarly, winding No. 2 (reversed) covers 3 to 4 in. With his technique, the full 0-to-10-volt input range covers just one quadrant.

NATIONAL AUTOMATIC TOOL CO.

FIG. 25.1. Drilling machine equipped with two-axis positioning table.

The Natco numerical positioning control has been designed for various drilling machines, Figure 25.1, manufactured by this firm. It is incorporated also in positioning tables that are available to other machine-tool manufacturers and for installation on existing machines by users. An interesting facet of this development is the avowed aim of Natco engineers to keep the system as simple as possible and to restrict it to minimum departure from the established practices and hardware employed in present-day machine tool control design. With the exception of three electron tubes, relays are employed exclusively in the logic sections.

The system now accommodates two axes up to 99.999 in. in length, but can be adapted for more axes and longer lengths. The storage is eight-channel 1-in. punched tape prepared on a special Natco machine. Both tape and programmer coding is straight decimal throughout. Positioning accuracy is within plus or minus 0.002 in. Repeatability is plus or minus 0.0002 in.

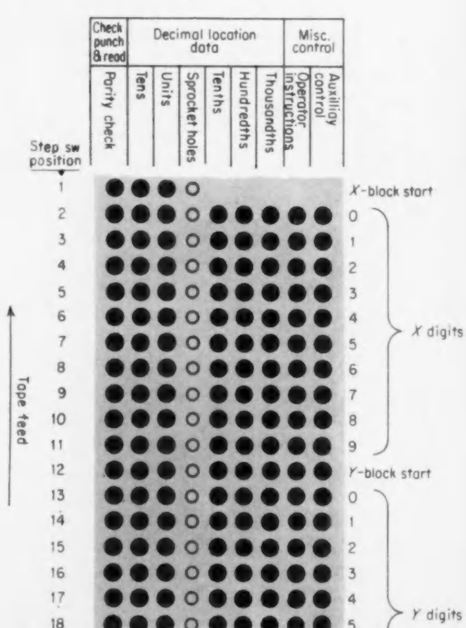
Positioning is done at the high speed of 150 in. per min along each axis. (Actual table speed is vector sum of axis speeds.) In the 24-x-36-in. table, a ¾-hp two-speed ac reversing motor powers each ball-nut leadscrew through differential gearing. The high-speed winding is energized until 1 in. from correspondence, where speed is reduced to 50 in. per min. At 0.1 in. from set-point, electric clutches associated with the differential gearing are energized to produce creep speed of 0.5 in. per min. At set-point, the clutches are de-energized and brakes applied. In practice, positioning is always done from the same direction. The direction of movement is not decided automatically by the control system, but is programmed onto the tape.

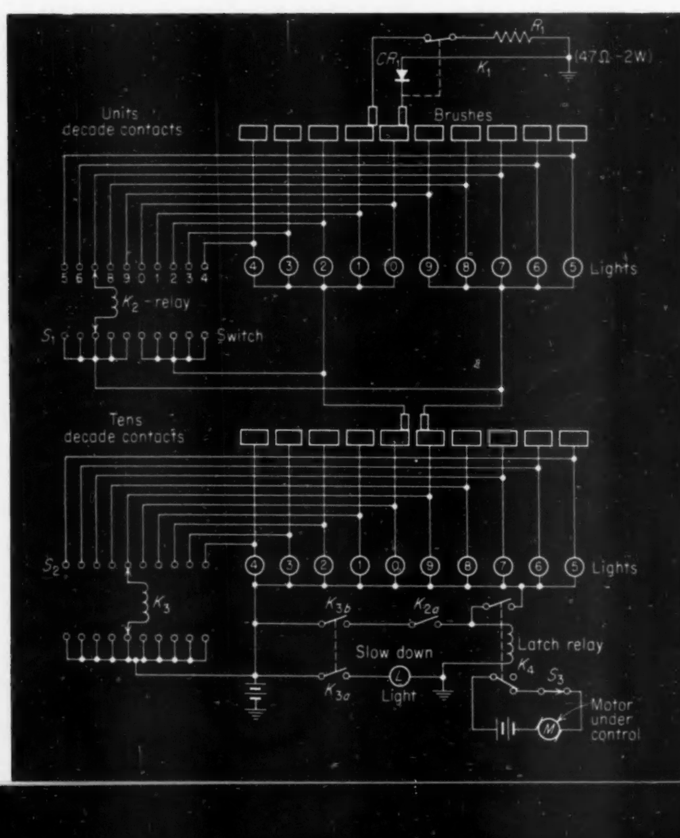
Tape reader

A hole position in one axis of motion occupies a 10-row block on the tape, Figure 25.2. The first column is for parity check; the next five columns contain the five-digit position data; and the last two columns are for operator's instructions and auxiliary control. The tape reader scans one row at a time, with information for each axis being stored in five 10-position stepping switches. Because information is read serially the tape reader contains a 25-position 10-level stepping switch that makes one step with each tape index. The need for this "information distributor" can be understood by an examination of just the X-axis block in Figure 25.2. If this entire block were read at one time, a total of 50 fingers or brushes would be employed for

FIG. 25.3. Schematic diagram of comparator circuit.

FIG. 25.2. Chart explaining arrangement of numerical data on tape.





the X-axis decimal location data. Each column of 10 brushes would be connected to the position terminals of a specific buffer-storage stepping switch. During a "read", each of the five steppers would home immediately to its energized position contact. In serial reading, however, only five brushes are used for decimal location data. Some means must be devised to channel the reader-brush signals to the five position contacts associated with the row of holes being read. This is the function of the information distributor, which is synchronized with the tape. As the distributor stepping-switch indexes, it connects each reading brush to a total of 20 contacts on the number storage relays.

Position measurement

The feedback transducer is a decimal-coded Coleman Digitizer, geared to each leadscrew. The digitizer unit converts mechanical shaft positions into an electrical output, in five-place decimal form. Each digitizer consists of one stator assembly, having five groups of 10 contacts. Each group of contacts is arranged in a circular pattern and is scanned by a dual brush rotor assembly. Five rotors, mechanically linked together by 10:1 gearing, provide electrical outputs which differ in ascending powers of ten.

Two solenoids are provided, which lift the high-speed rotor brushes from the stator contacts during rapid traverse, where a high degree of accuracy is not required. The brush corresponding to the most significant (tens) digit is energized just 10 times over 99.999 in. of travel. In contrast, the brush associated with the least significant (thousandths) digit, transfers 10 times with every 0.01 in. of travel. To minimize wear, the brushes of the high-speed discs are lifted during rapid traverse. Correspondence along any axis is determined by comparing the settings of the five buffer-storage limit switches with those of the coded discs.

A schematic diagram for the tens and units sections of the position comparator is shown in Figure 25.3. Switches S_1 and S_2 represent the units and tens stepping switches, which are stopped at contacts determined by tape information. At the start of a positioning cycle a plus voltage is put on the S_2 contacts. When a brush encounters the corresponding segment of the tens commutator (segment No. 9 in this case), the circuit is extended from plus to the contacts of switch S_1. Now, leadscrew rotation continues until the units brush hits segment No. 7. At this point the circuit is completed from plus to ground. The K_2 and K_3 relays are energized and lamps 9 (in the tens bank) and 7 (in the units bank) are lighted. Contacts K_{3b} and K_{2a} close now to actuate the main control relay and stop the drive motor.

System

26 WESTINGHOUSE ELECTRIC CORP.

Westinghouse offers two basic lines of positioning systems, which differ only in the feedback element used. Where applicable, linear synchros connected in a stepless switching arrangement are geared to a precision ballnut leadscrew. If greater accuracy is required, especially over long lengths, the Westinghouse "Nultrax" transducer is used instead of the measuring function of the screw. Both systems follow a building-block approach which allows the majority of systems to be assembled from standard off-the-shelf units. All electronic circuitry has been transistorized and is furnished in plug-in modular form.

The Nultrax transducer is basically a helical differential transformer. As shown in Figure 26.1, it consists of a cylindrical steel bar and a pick-off sleeve. It can be supplied in any practical length required (at present a 40-ft unit is being adapted to a drilling machine). On lengths over 7 ft the sleeve is supplied in horseshoe form, allowing the bar to be supported on rolls if this is needed for mechanical clearance.

A two-start spiral thread is ground on the cylindrical bar and the primary winding placed in these grooves. The two windings are joined at one end and brought out to slip rings at the other, forming a bifilar coil. When excited by an ac voltage there is no external field due to the bifilar formation, but each wire is surrounded by a fringinal magnetic field.

The pick-off sleeve carries a bifilar winding on its inner surface, of the same pitch and lead as the primary coil. Clearance between the sleeve and bar is not critical and allows relative linear motion. All windings are embedded in an epoxy resin which, with the steel construction, provides a rugged element.

When an ac voltage is applied to the primary winding, alternate turns carry current in opposite directions, Figure 26.2. Positioning the secondary sleeve so that its turns line up with adjacent primary turns causes a maximum voltage to appear across its terminals, Figure 26.2A. If the sleeve is displaced a distance equal to half the winding pitch, each of its turns is now equidistant from primary turns and the output of the secondary is zero or a null. Displacement equal to one-half the winding pitch again will result in realignment of turns—but with any given secondary turn now opposite a primary conductor carrying current in an opposite direction. The secondary output is once more a maximum but in the opposite phase. Continued linear displacement of the sleeve results in its output being a sinusoidal function of position. The pitch of the windings is so chosen that alternate nulls are a convenient distance apart; 0.1 in. If the primary bar is rotated, any one null is moved forward. In a full revolution, the null is shifted by 0.1 in.; 1/1,000 of a revolution corresponds to a linear displacement of 0.0001 in.

All possible sources of error in the Nultrax transducer are inherently eliminated by its design, with one exception. Local errors in the primary winding are averaged out over 50 to 70 turns in the secondary sleeve and become negligible. This is in contrast to lead-

screws which may rest on high points. Winding errors in the sleeve are of no consequence since its turns are engaged in an identical manner in all positions along the bar. Eccentricity and tilting of the sleeve have no effect on accuracy since null positions are in a plane at right angles to the axes of both these possible misalignments. Primary-bar bearings are designed so that any error caused by wobble is less than 1 microin.

The only possible source of error is an accumulative error in grinding the primary grooves. Controlled grinding techniques and electrical correction keep these well within accuracy requirements.

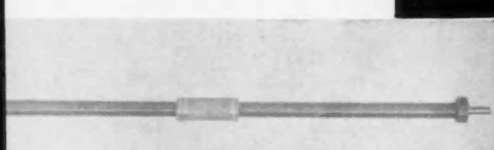
With respect to performance, Nultrax transducers can be supplied with an accuracy of one part in 400,000 in lengths up to 40 in. Longer units have an accuracy of one part in 100,000, the variation being caused by practical considerations of temperature variation. Repeatability is better than plus or minus 0.0005 in. Noise present in a null amounts to an electrical signal corresponding to a linear displacement of less than 0.00001 in. Stability is assured through the use of electronic circuitry which is fundamentally drift free. Temperature correction is available through a calibrated manual dial if desired.

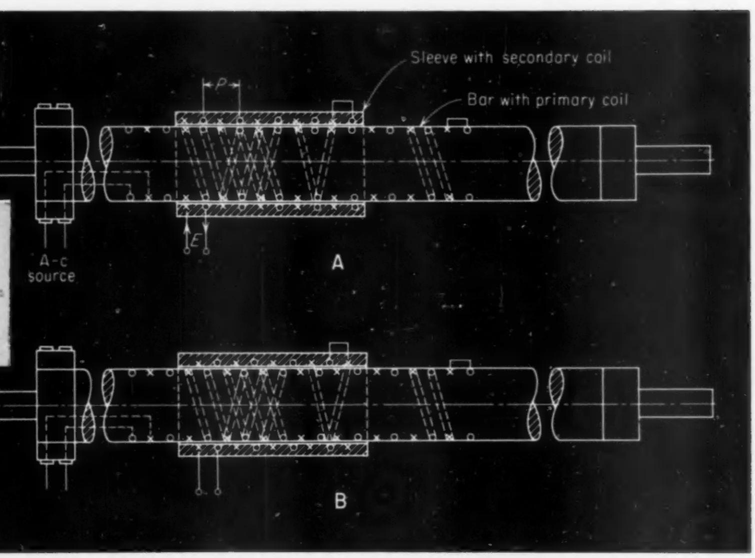
System design

A block diagram of a single co-ordinate positioning system is shown in Figure 26.3. The Nultrax primary bar is mounted parallel to the leadscrew and the sleeve mechanically attached to the machine tool slide.

Basically, the system can be divided into coarse and fine sections. Coarse positioning is accomplished in conventional manner. A linear synchro-type data element gives an indication of table position, which is compared against the command signal from punched tape or selector switches. The error signal drives the machine tool slide to the nearest 0.1 in. At this point an electronic coarse/fine switch brings the Nultrax system into effect. Command signals corresponding to 0.0001-in. increments cause the primary bar to be rotated to the corresponding position by means of the instrument servo loop. This places the specific null in the precise command position. Displacing the machine tool slide relative to this null position results in a signal at the output terminals of the secondary sleeve. This signal is amplified and used to drive the slide.

Variations of the above are possible. Straight ac drives with clutches and brakes can be used as well as ac and dc servo motors. In some instances the Nultrax bar may be geared directly to the leadscrew, eliminating the transducer drive loop. In certain applications where highest accuracy is not required the Nultrax transducer may be eliminated. Here, linear synchros in a stepless switching arrangement are used directly as the feedback transducers.





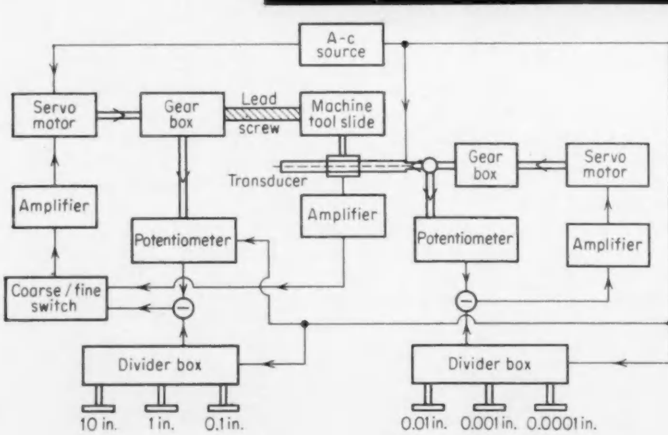


FIG. 26.1. Nultrax linear position transducer.

FIG. 26.2. Schematic shows bifilar arrangement of primary and secondary coils.

FIG. 26.3. Block diagram of Westinghouse positioning system with potentiometer feedback.

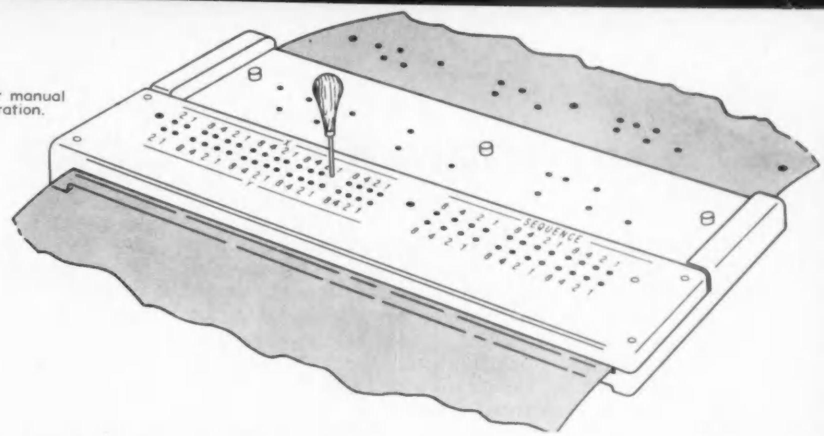


FIG. 27.1.
Templet for manual tape preparation.

System

27 ELECTROSYSTEMS, INC.

The "Electropoint" system is offered to equipment builders as a complete control package with or without application engineering. Electrosystems also designs and manufactures special machines that are available with numerical control. Cost ranges from $1,200 per axis (for manual input and control unit only) to $7,000 per axis (including tape reader, control console, servo drives and positioning table). Among present users of Electropoint are Burg Tool Co. in drilling machines and Sheridan-Gray Co. in stretch-forming machines. Positioning accuracy is plus or minus 0.001 in.

The special Mylar tape, Figure 27.1, is 10 in. wide. Just two rows of this tape are sufficient to carry all position and auxiliary command data for one hole location. The tape language is binary-coded decimal. A complete two-row field is read at one time so that no buffer storage is required. Simple transistor matrices convert tape data into decimal form for use in the comparator, Figure 27.2. Auxiliary-command information is read into an 11-position stepping switch, providing a choice of 11 machine operations. A series of six different auxiliary functions can be initiated without moving the tape. Standard 1-in. tape equipment is also available.

Position measurement

The feedback transducer is a five-band decimal-coded disc converter coupled directly to the leadscrew. The brushes riding the high-speed bands are automatically lifted during rapid traverse. The output of the converter is fed to the position comparator, which consists of a group of transistors functioning in the switching mode. The comparator circuits control the direction of positioning; the starting of the drive servo at rapid traverse (100 in. per min); the switchover to slow speed (5 in. per min) near set-point; and the application of magnetic brakes.

The control panel, Figure 27.3, displays at all times the exact position of the table in both X and Y axes. The position indicator consists of two banks of pilot lamps, one for the X axis and the second for the Y axis. A column of 10 lamps in either bank is assigned to each digit of the five-digit position number. Individual lamps in any one of the columns are wired to the commutator segments of the converter band that is associated with it. Thus, the lamps are illuminated in numerical sequence as the brushes wipe across the commutator bands and constitute an electronic micrometer.

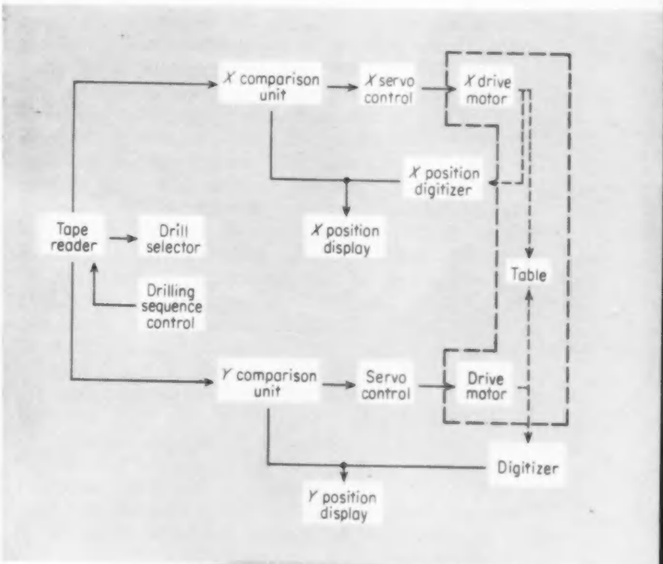


FIG. 27.2. Block diagram of two-axis Electropoint positioning control.

FIG. 27.3. Control panel features continuous display of machine position.

NORDEN-KETAY CORP.

Another newcomer to the numerical control field, the Data Systems group of Norden-Ketay, is offering semi-standard point-to-point positioning systems for almost any type of machine, either as new equipment or for retrofit. A prototype model is operating, but no systems have been delivered to the field. The basic functions are performed by the standard packages listed below, which can be combined to handle any degree of automaticity and any number of axes or auxiliary functions.

▶ *Position Measurement and Display Module*—This equipment includes a bed-mounted precision rack which drives a coded-disc analog-to-digital converter through a pinion. The pinion and the converter move with the controlled machine element. The output of the converter is digitally displayed to the operator at all times, indicating the position of the machine carriage within 0.001 in. The operator must still move the table manually (or with normally available power drive) but it's easier for him to accurately determine carriage position.

▶ *Numerical Control Module*—In conjunction with the above module, numerical control permits positioning and auxiliary function control by setting selector switches and other manual adjustments on a control console. This system includes data-handling circuitry, a comparison network, and a power servo. The power servo may or may not be supplied by Norden-Ketay.

▶ *Automatic Control Module*—This unit adds punched tape input to the capabilities of the above two modules. The tape can be prepared on a separate tape punch, or at the same time the table is being initially positioned. In the latter case, the instructions are entered through the manual controls and the tape punched simultaneously with machine operation.

All inputs to the system are in straight decimal, although all internal manipulations, including output of the analog-to-digital converter, are in binary-coded decimal. Maximum slewing speed is 360 in. per min. Maximum axis length is 40 ft, with an overall positioning accuracy throughout this range of 0.001 in. plus or minus 0.0005 in. Estimated command read-in time plus time to stop from slewing speed in an average system is 1 to 3 sec for each axis. The axes can be positioned sequentially or simultaneously depending on whether part of the equipment is time-shared.

A typical control console, including tape input, is about 30 x 24 x 48 in. It uses about 100 relays and 350 transistors for storage, display, and control.

Input coding

Manual input is in straight decimal code, using six ten-position rotary selector switches for each controlled axis (from thousands of inches to thousandths of inches), with sufficient additional switches to handle necessary auxiliary functions. Coding circuitry converts the switch outputs into binary-coded decimal, the internal code of the system. Each manually-set digit is prominently displayed to the operator for verification.

The recorded input medium is standard eight-channel 1-in.-wide punched tape. The first four channels of each row are used to specify a single digit (in binary-coded decimal) of command input information, while the fifth channel provides a parity check on the first four channels. The sixth, seventh, and eighth channels provide space for three additional bits of auxiliary command information. The tape is read sequentially, a row at a time, and the information is stored in relay buffer storage. From there it is available in parallel form. The keyboard-type tape unit accepts straight decimal

Overall system operation

Figure 28.1 shows a system schematic for one axis in which part of the equipment is time-shared. Binary-

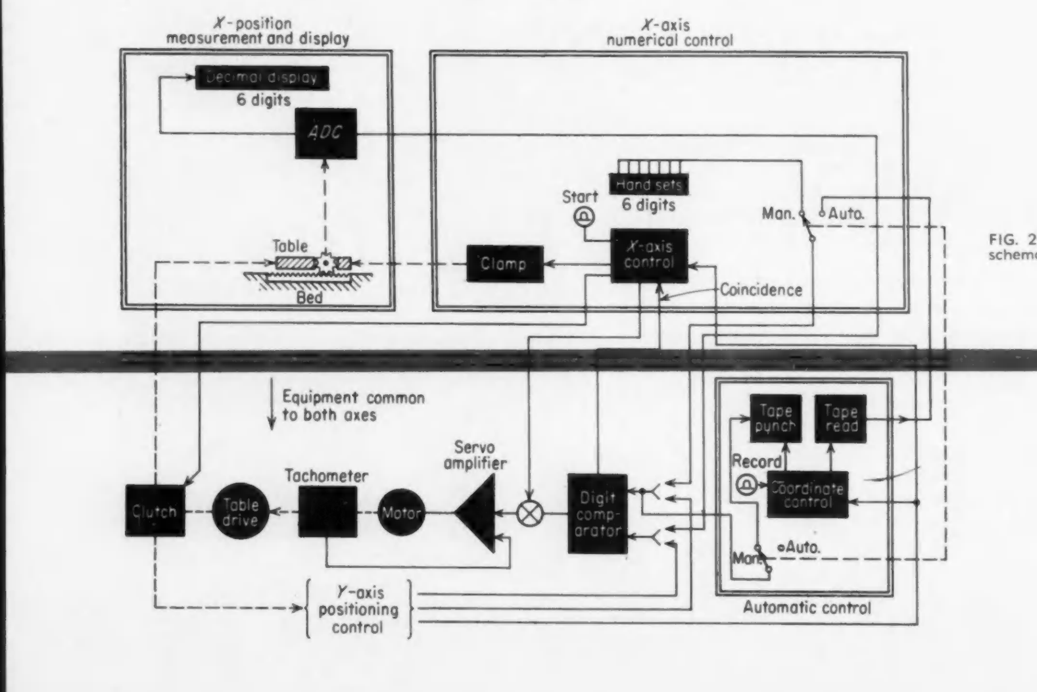


FIG. 28.1. Simplified schematic for one axis.

coded decimal information from the precision-rack-driven analog-to-digital converter (representing actual table position) is compared with the tape or manually introduced desired-position information in the digital comparator. The latter generates an output signal proportional to the algebraic difference of the two inputs; the amplified signal drives the controlled machine element through a power servo and an axis-selecting clutch assembly. When coincidence is reached in the first axis a clamp is applied and the comparator and power servo are switched to the next axis. When all of the axes are positioned, the operation begins.

The number of auxiliary functions that can be handled is limited only by the capacity of the auxiliary storage registers. In general, these auxiliary functions are simple selection operations that can be assigned some arbitrary coded address, and programmed into the three auxiliary function channels available in each tape row.

System

29 WARNER & SWASEY RESEARCH CORP.

The Probomat point-to-point positioning system is a packaged control designed for application to both linear and rotary motions. Cost of a two-axis control, including console, tape reader and two locating units, Figure 29.1, is $9,950. The locating (Auto-Set) unit is coupled directly to a leadscrew, worm or pinion and performs a pure measurement function. The positioning drives are independent of this unit and may be of any type. Conventional ac squirrel-cage motors with two-speed (100-to-1 ratio) clutch-controlled gearing are recommended for the average application.

Another unit, the Pilot Probomat, is designed for installation where it is desired to keep positioning control mechanically independent of the machine drive. In this case an instrument-type metering device is installed along each axis of motion. This metering device carries a pilot slide which is positioned by the control equipment to the desired set-point. The main slide is then driven until a sensitive limit switch contacts the pilot slide. The metering unit contains a peg and pawl mechanism, with pegs spaced 1 in. apart. The carriage of the pilot slide is equipped with a pawl which can engage any of the pegs by automatic selection. The decimal setting between inches is done by a 1-in. precision leadscrew actuated through tape controls by an Auto-Set unit. The same tape controls the peg selection and other functions of the machine.

The input medium is standard 1-in. 8-column punched paper tape using binary-coded decimal numbers. Each row on the tape represents one digit of the position number expressed in inches and decimal fractions of inches or, in the case of rotary motion, in degrees and decimal fractions of degrees. Control of an unlimited number of auxiliary functions can also be programmed onto the tape.

The tape reader scans one line at a time and stores the number signals in a bank of stepping switches. At the start of a positioning cycle, the main drive motor for a given axis is energized and continues operation until the discs in the Auto-Set unit indicate correspondence to the input signal. The Auto-Set employs a coarse and fine range so that actually two correspondence signals are generated. The first clutches the main drive into slow speed while the second de-energizes the motor and applies a brake.

The Probomat incorporates a minimum of electronic components, relying on industrial-grade relays for logical functions. The locating unit, which is attached to each leadscrew, is a complete pre-engineered package, measuring 15 x 5 x 10 in. and weighing 35 lb. Power requirements of the control system (not including the main drive motors) is 115 vac, single phase.

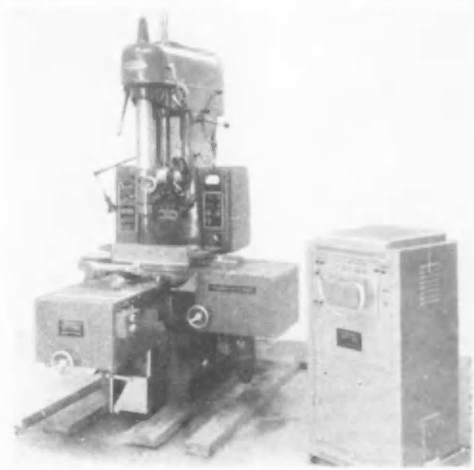


FIG. 29.1. Moore jig borer equipped with Probomat tape control.

The accuracy potential of a Type A Probomat control is plus or minus 0.0001 in. over an axis length of 100 in. As in all applications of numerical controls, the machine itself is an important factor in determining the actual working accuracy of a point-to-point positioning system. Because present-day commercial tolerances are such that the majority of machines offer working accuracies not quite as good as plus or minus 0.0001 in., the capabilities of the Type A control is sufficient for most uses. Where extremely precise machines are to be equipped for numerical control, an alternate form of Probomat, designed as Type HP and having a control accuracy of plus or minus 0.00001 in., is available.

Present applications of the Probomat equipment include jig borers and grinders, a boring mill, several types of measuring machines, a gun-drilling machine, four rotary tables (12, 24, 50, and 84 in. diam.) and a 20 x 30 in. rectangular-coordinate table.

System

30 EKCO ELECTRONICS, LTD.

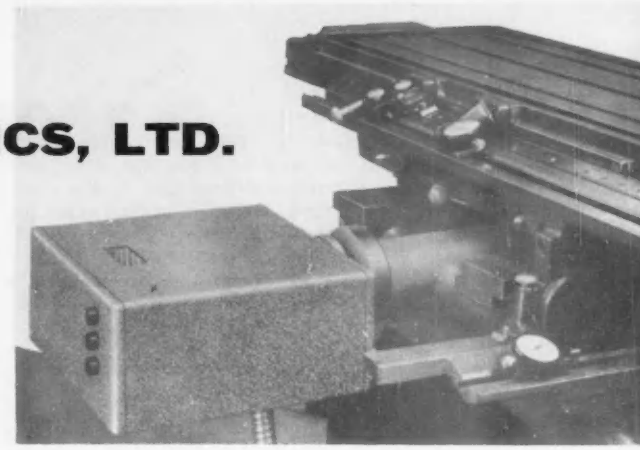


FIG. 30.1. Traverse unit showing compact size.

The Ekco machine tool control type E117 is a simple and reliable system adaptable to both new and used equipment. All-electric rather than electronic, its four Wheatstone-bridge networks and 22 relays for sequencing control provide a resetting resolution to within 1/500 of a turn over a range of any 1,000 revolutions of the leadscrew.

To overcome backlash, the approach to final position is always from the same direction, and impulse operation used during the final stages of travel reduces stiction effects. It is designed to present a standard 10 TPI pitch to the measuring system, and is capable of a resetting accuracy of 0.0002 in.

The basic system consists of a traverse unit for each leadscrew and a control unit for both traverses.

The traverse unit

The traverse unit, Figure 30.1, contains the drive motors and pickoff potentiometers and counters for position determination. The position-measuring system, directly coupled to the leadscrew, comprises a high-resolution 360-deg potentiometer, a 0-0.1 in. dial gage indicator, and three three-decade counters with each decade coupled to a low-resolution potentiometer.

The high-resolution potentiometer, used as the slave arm in the Wheatstone-bridge servo controlling the last three digits of the position information, is wound over 360 deg with a gap of only one wire width between the ends of the winding.

To the wiper is connected a dial gage calibrated from 0 to 0.1 in. This in turn operates the final digit of the three-decade mechanical counter, once in each revolution. Each of the three dials of the mechanical counter is connected to a wiper of a 360-deg low-resolution potentiometer. These form the slave arms of the remaining three Wheatstone-bridge servos controlling the first three digits of the position information. These three low-resolution potentiometers operate from a supply of 5 volts, compared with 25-30 volts for the high-resolution system. This low resolution of only 1 part in 20 is sufficient to provide an unbalance signal when the dials are half-way between two digits.

The drive system uses two motors feeding through a differential system to the leadscrew.

For rapid approach to position, a ¾-hp series-wound motor is used as an on-off servo and is controlled by sequential balancing of the first three-digit Wheatstone-bridge networks. When the leadscrews attain the particular revolution in which the final selected position lies, control changes over to a low-voltage, permanent-magnet, 0.03-hp dc motor driving the output shaft at ¾ rpm. In the last few thousandths of movement, this motor changes over from continuous to impulse operation, breaking down the low-velocity stiction.

All the drive system and position potentiometers are contained in the traverse unit, which measures only 9 x 9 x 4½ in. In addition to the counters, which provide a visual check of leadscrew position, there is a datum shift mechanism to allow the measuring system to be uncoupled from the drive so that any position of the table can be chosen as datum. Pushbutton control of the motors on the traverse unit, both at high and low speeds, facilitates initial setting.

Control system

All control functions for the system are incorporated in the control unit (only 15 x 12 x 12 in.), which is completely self-contained with its own power supplies.

Control information for each traverse is set up on a six-decade dial system which is direct reading in inches and decimals to the nearest 0.0001 in. Each dial is separately illuminated from behind and displays only the digit selected. Although the dimension is set up as six digits, only four Wheatstone-bridge networks are used. The three low-resolution bridges handle one digit each, while the one high resolution bridge handles the last three digits as a composite quantity.

To avoid the ambiguities that occur with mechanical counters on the "carry" position, the first three digits are examined sequentially, permitting the same potentiometer to be used in association with three independent tapping switches and providing the master ratio arms for each of the first three digits.

After the required dimension has been set on the dials (schematic diagram, Figure 30.2), all of which appear illuminated, depression of the "start" button operates sequencing relays to select the first digit (tens of inches). Once selection has been made, the start relay releases the table clamps; then, after proving circuits verify this step as complete, the main contactor circuit is made. If the bridge circuit corresponding to the first digit is unbalanced, the sensitive center-stable polarized relay provides direction information to the motor, which rotates to bring the bridge to balance. During this operation the lights behind all dials but the first are extinguished to show this section is in control.

When balance is achieved on the first bridge network the detector relay drops out, passing a signal to

the sequencing relays. These select the next digit network and at the same time illuminate only the second digit dial. The balancing sequence is repeated until arrival at the balance conditions switches control to the third digit.

A similar procedure occurs with the third digit. When balance is achieved the sequencing circuit switches off the main motor and applies regenerative braking to prevent inertia from causing a run-on in excess of 1/10 in. This is the point at which, with the associated bridge disconnected on balance in readiness to pass control to the final high resolution system, a run-on would remain uncorrected.

The last three digits are treated as composite quantity in one bridge network. Each digit is associated with an independent ten-step potentiometer, and the voltages from these are correctly weighted and added in series for comparison with the position-measuring potentiometer in the traverse unit. In detail, a 25-volt dc source supplies this position potentiometer and the ten-step potentiometer in the control unit operating on the first of this group of three digits. The ten steps are obtained from preset-taps on a single winding potentiometer, avoiding the use of close-tolerance resistors. A voltage from a conventional two decade Crompton potentiometer operating from a separate dc source is injected in series with the tapping point of this potentiometer and the detector relay. This voltage represents the final two digits. Thus, the three single-pole ten-way switches select tenths, hundredths, and thousandths of the voltage applied to the position potentiometer and apply the sum of the selected voltages to the detector relay.

With the third bridge balanced, the sequencing circuits now select the auxiliary motor, which runs to balance this summed voltage against that at the wiper of the final position potentiometer in the traverse head. Because these last three digits are treated as a composite, all three dials are illuminated during this operation.

As the system nears balance, a backing-off potential is injected into the detector arm to cause a premature apparent balance. When this apparent balance is reached (within about 0.002 in. of the required position), an impulsing circuit is brought into operation on the motor-control relays to impulse the auxiliary motor in steps of 0.0001 in. until final balance is obtained, thus reducing stiction effects.

One feature of the design is that the approach to final balance is always unidirectional, and is achieved by the injection of a backing-off potential prior to final balance. Choice of polarity governs the apparent balance point: if the direction is decreasing compared with the example given earlier, the delayed balance causes the drive to continue past the required position; on arrival at the apparent balance point, the backing-off potential is removed and the system approaches its final position unidirectionally. With the overshoot adjustable, all backlash errors on any machine can be eliminated.

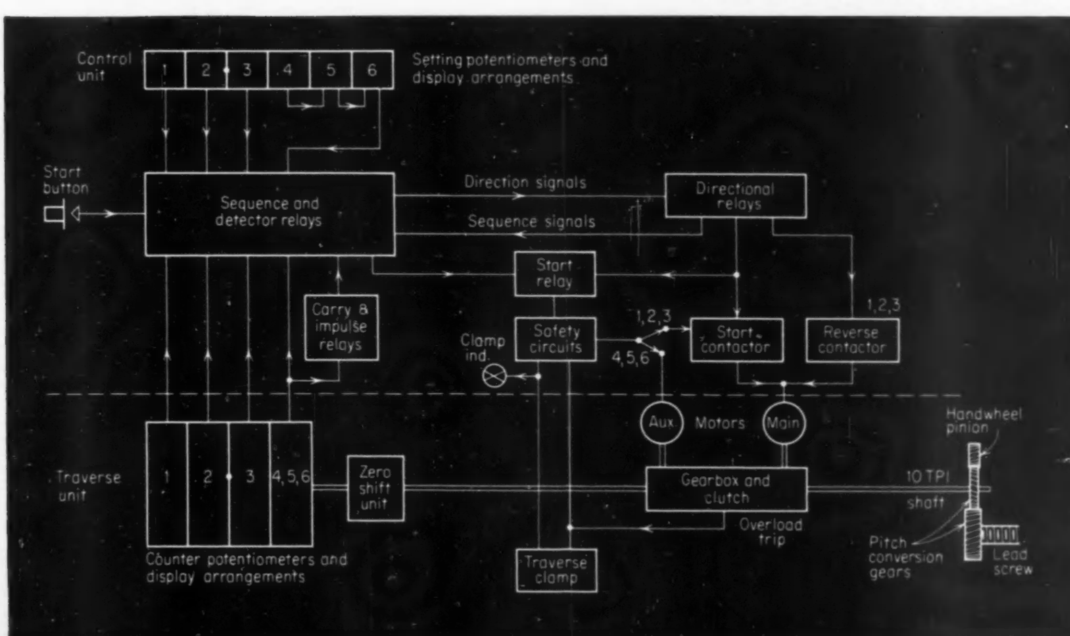
Ambiguities in the final high-resolution potentiometer position are overcome by the "carry" circuit. With the overshoot system of backlash correction, the wiper may under certain circumstances cross the boundary between the high and low potential ends of the 360-deg winding "in reverse". The "carry" circuit is brought into operation and released by the abrupt potential change, which occurs when the wiper crosses the boundary and permits it to travel far enough beyond to provide correct backlash correction.

Punched-card control

A punched-card storage system is still under development; preliminary details show that the cards will be quarto size and there will be facilities for punching up to 144 holes per card. This will enable recording of positional information for 12 holes of the same tool size per card. Where more than 12 holes of the same tool size are required, cards may be taped together for feeding through the transport mechanism.

The card coding will be straight decimal. The card reader merely substitutes a series of feeler contacts for the ten position rotary switches, and provides a means for stopping the machine when all the information on the card has been used.

FIG. 30.2. Block diagram of single traverse system.



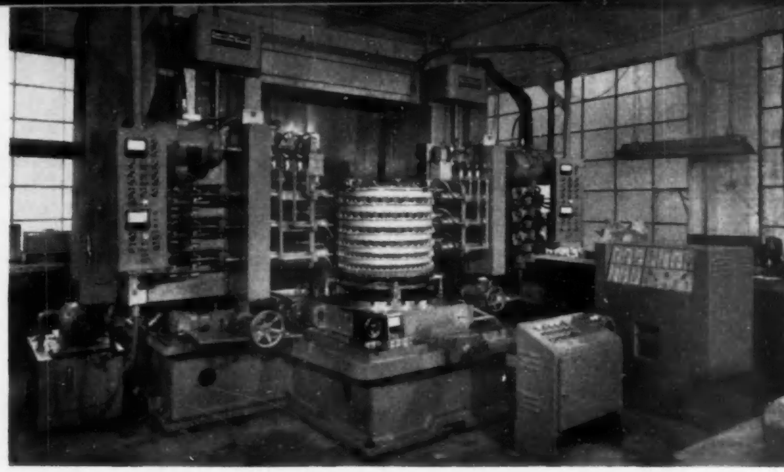


FIG. 31.1. Six-spindle boring mill for machining jet-engine casings.

System

31. CLEVELAND INSTRUMENT CO.

With seven systems in the field (the first installed about a year and a half ago) and an impressive backlog of orders, Cleveland Instrument is among the more active of the point-to-point positioning system suppliers. The major activity to-date has been in the angular positioning of Omnidex indexing tables manufactured by Superior Machine & Engineering Co., Detroit. The six-spindle boring machine shown in Figure 31.1 is a typical application for the table. This system, incidentally, works just as well for straight-line positioning. There is no standard package, and semi-custom designed systems will be supplied to fit specific machines.

Either Remington-Rand punched cards or standard 1-in.-wide, eight-channel punched tape can serve as the input medium. Position measurement is analog, using a wire-wound continuous potentiometer for rough positioning and a special electronic vernier (patents pending) for fine positioning. This yields a programming resolution of 1 sec of arc, and an accuracy of plus or minus 3 sec of arc. In the straight-line positioning systems, accuracy is plus or minus 0.0001 in. On the machines supplied up till now, table drive is by a two-speed ac motor through a clutch-selected two-speed gear train. Average positioning time with this arrangement is about 10 sec point to point, and maximum traverse speed with a 41-in.-diam table is 1.5 rpm.

Input coding

Figure 31.2 shows a Remington-Rand card for programming this boring mill. The first 14 columns are used to enter duplicate coding of table angular position. Degrees (in direct decimal code) are punched in columns 1, 2, 3 and 8, 9, 10; minutes in columns 4, 5 and 11, 12; and seconds in columns 6, 7 and 13, 14. Duplicate codes assure proper card preparation and code reading.

Columns 15 through 26 contain duplicate coding of left and right spindle heights in tenths of an inch. Maximum spindle height is 39.9 in. Since only one spindle on each of the two slides is used for machining at any given time, rows 7, 8, 9 in the tens columns (columns 15, 18, 21, 24) of the spindle height fields (not used for height coding because of 39.9 in. limit on vertical travel) are used to indicate which of the three spindles is to be used. A punch in row 6 of the same columns indicates that this is the last operation for the particular slide.

Position transducing system

Rough positioning to 10 min of arc is achieved by means of a straightforward resistance-bridge-balancing network. The resistance ratio of the fixed arm of the bridge is set up by resistor-switching selector switches in the programmer. The other arm of the bridge is a continuous 360-deg wire-wound potentiometer fastened to the moving table. The table is positioned until the resistance ratio of the follow-up table-position-measuring potentiometer is equal to that of the programmed bridge arm. Control is then switched to the fine-positioning system.

The most interesting portion of the system is the vernier linear-differential transformer system shown schematically in Figure 31.3 (for straight-line positioning; it is wrapped in a circle for angular positioning). Fastened to the moving table are 360 differential-transformer armature slugs on exact 1-deg centers. On the machine base there are 15 exciter-coil/output-coil differential-transformer structures on exact 56-min centers. Since the coils on the two legs of the differential-transformer output elements are wound series-opposing, transformer output is zero when a slug is exactly aligned with a transformer structure.

As shown in Figure 31.3, if an armature slug is exactly in line with the first differential-transformer structure, each successive slug will be an additional 4 min off center from the corresponding transformer structure until the 15th slug is directly in line with the 16th transformer structure (if there were a 16th differential transformer). Thus by means of this vernier technique, 1 deg can be broken down into 4-min intervals simply by positioning an armature slug directly in line with the proper transformer structure.

To achieve the final system resolution of 1 sec of arc, the 4-min vernier intervals must be further broken down. This is accomplished by nulling transformer output to a specified voltage instead of to zero. Since transformer output varies linearly with misalignment of the armature slug, selecting a specified output voltage by means of programming selector switches and nulling

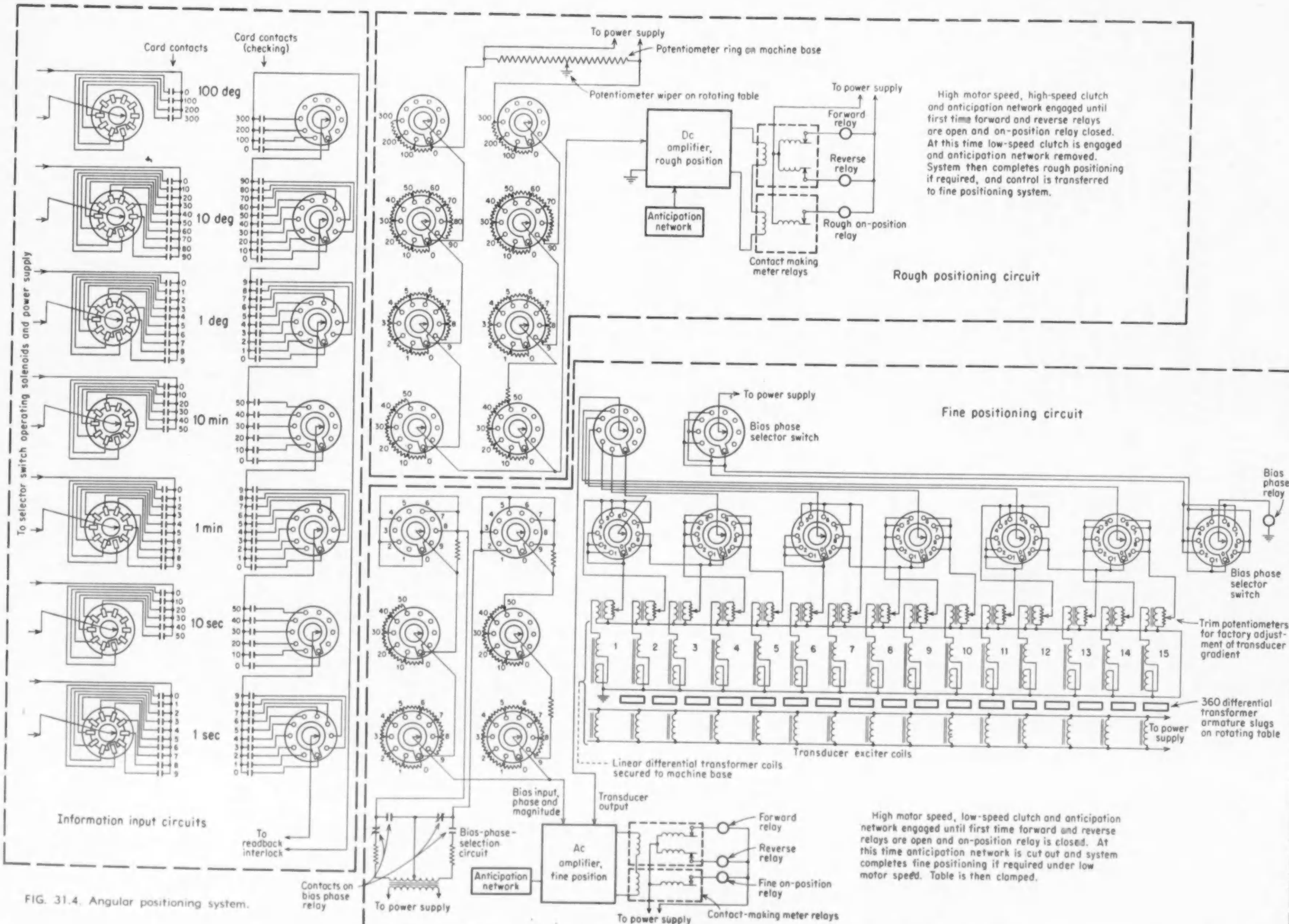


FIG. 31.4. Angular positioning system.

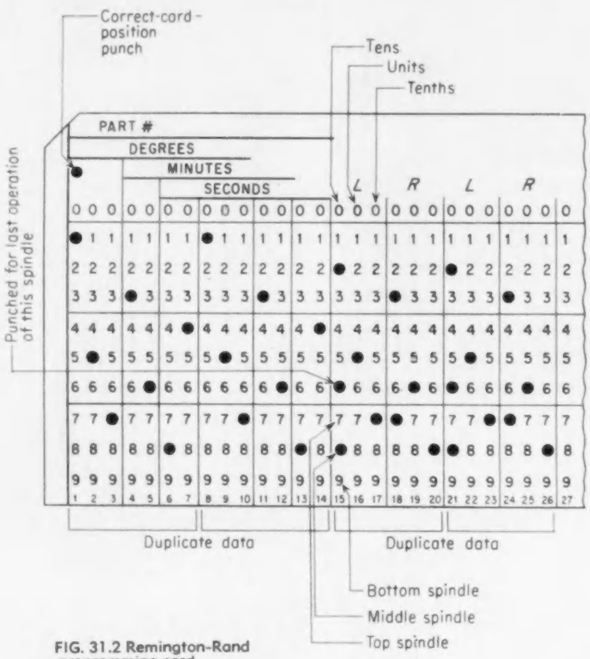


FIG. 31.2 Remington-Rand programming card.

transformer output against this programmed voltage (or bias) permits the table to be positioned to any angular second of arc.

An overall system

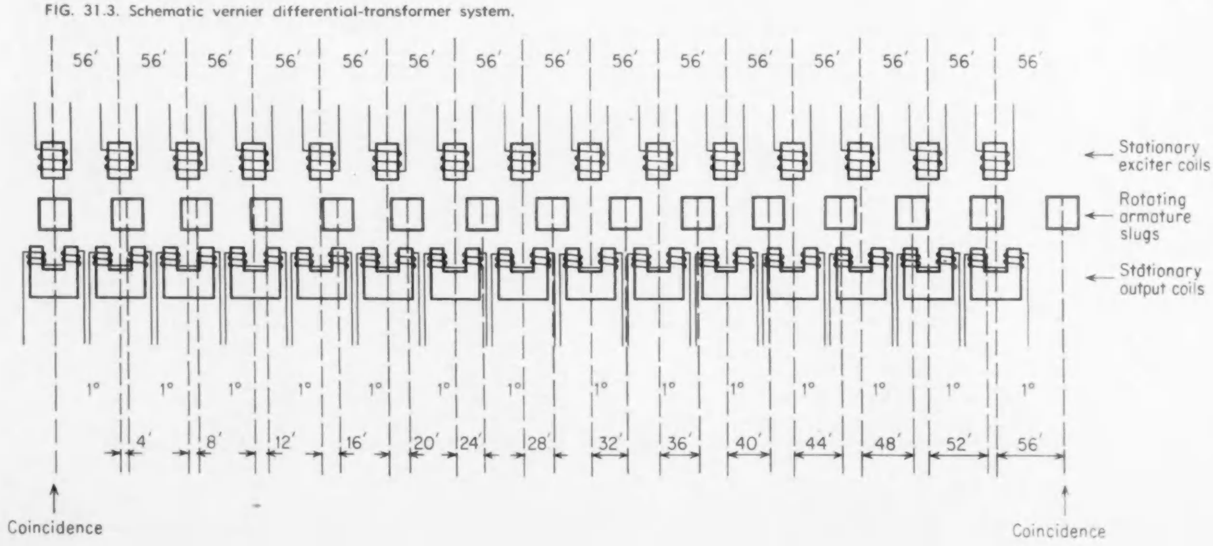
Figure 31.4 shows the angular-positioning portion of the six-spindle boring machine programming system. Multistage decade selector switches are used to store card information and set up internal conditions. All of the stages shown on any one horizontal line belong to the same selector switch.

The selector switches are positioned by solenoids in accordance with the information read from the cards by the card contacts. The same information (supposedly) is read by the checking-card contacts. If the two sets of information match, the readback interlock relay closes and positioning can begin. The 100-deg, 10-deg, 1-deg and 10-min selector switches set up a resistance ratio which is opposed in a bridge circuit by the 360-deg table potentiometer. The unbalance signal from this bridge network is amplified in a dc amplifier and drives the coils of two contact-making meter relays. One of the contact-making meters is a two-contact polarity-sensitive unit which energizes either a forward or reverse relay, depending on which way the table should travel to null. The other contact-making meter is open for either polarity error, and only closes when the null point is reached. In actual operation, an anticipation signal is added (false null) during initial positioning, and the table travels at top speed (high motor speed, high clutched-in gear ratio) until the first time the rough on-position relay closes. At this time the anticipation network is cut out, the low-speed clutch is engaged, and the system completes rough positioning if necessary. Control then switches to the fine-positioning system.

The fifth stage of the 10-min selector switch, and the fifth through tenth stages of the 1-min selector switch specify the active differential-transformer structure (or the vernier-obtained 4-min band within which the system is to be positioned) by means of stage coding.

The next problem is to select the bias magniture (a voltage representing the misalignment of an armature slug and the transformer structure, required to resolve the 4-min overall interval into 1-sec increments) and the direction of the bias. The sixth stage on the 10-min selector switch and the 11th stage on the 1-min selector switch select bias phase (or direction) by either energizing or deenergizing the bias-phase relay. Contacts on this relay in the bias-phase-selection circuit determine the phase of the bias signal as it is applied to the ac fine-positioning amplifier. The magnitude of the bias voltage is determined by the resistance network set up by the fourth and fifth stages of the 10-sec and 1-sec selector switches. The bias signal (of correct magnitude and phase) and the output of the series-opposed output coils on the specified differential transformer are applied to the ac fine-positioning amplifier through a summing network. The output of this amplifier goes to contact-making meter circuitry, which is very similar to the rough-positioning circuitry. When final position is attained, the table is clamped.

FIG. 31.3. Schematic vernier differential-transformer system.



Electrochemical methods for PROCESS-STREAM analysis and control

Versatile electrochemical and titrimetric analysis methods are common in the laboratory, but have not yet been employed extensively on continuous processes in the plant. The main reason for this is not inherent drawbacks in the methods themselves, but rather the limited understanding of their capabilities, limited experience in their application, and lack of commercially available instruments.

These methods deserve much more attention than they have received (the large-scale application of electrochemical methods to continuous-process monitoring and control seems to be only a matter of desire and development). This article has been written to draw attention to electroanalytical techniques and thus spur their use in continuous process control.

T. C. WHERRY, Phillips Petroleum Co., and
D. D. DeFORD, Northwestern University

All electrochemical methods, with the exception of conductometry, depend on the relationship between current and voltage at an indicating or "working" electrode. Just as absorption spectra form the basis for developing a spectrophotometric method, so current-voltage curves (polarograms) form the basis for electroanalytical methods.

POLAROGRAPHY PRINCIPLES

The polarographic method, versatile and sensitive, is able to analyze inorganic metal ions as well as such organic materials as aldehydes, ketones, acids, esters, halogen compounds, nitro compounds, sulfur compounds, and peroxides. (Even when the compound to be determined is not itself electroactive, indirect polarographic procedures for its determination can sometimes be devised.) In practice, the concentration of the substance is adjusted to the range of 10^{-4} to 10^{-3} M; special techniques extend this range to 10^{-6} M or even lower.

If a direct current is passed between two electrodes immersed in an electrolyte solution, an electrochemical reaction occurs at each electrode:

- ► oxidation takes place at the anode
- ► reduction takes place at the cathode

The current that flows at any given applied potential depends, in particular, on the nature of the electrodes and the nature and concentration of the components in the solution. In practice, one electrode is nonpolarizable and of low resistance. It is a reference electrode, with a potential known and constant irrespective of current magnitude or direction

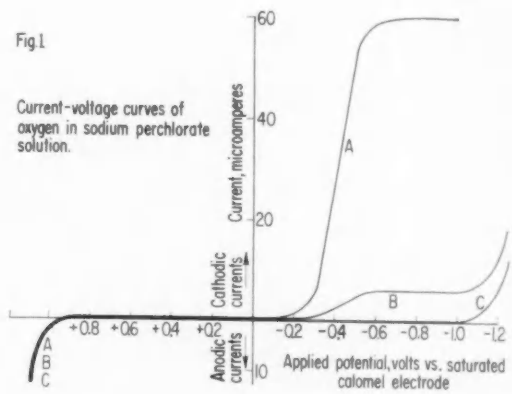


Fig.1

Current-voltage curves of oxygen in sodium perchlorate solution.

at the electrode. A saturated calomel electrode, SCE, is one of the most common reference electrodes. The other is the indicator electrode, whose potential-current characteristics depend on the nature and concentration of the electroactive species.

A plot of current as a function of applied potential is called a current-voltage curve or polarogram. Typical curves in Figure 1 were obtained with aqueous sodium perchlorate solutions containing varying amounts of dissolved oxygen:

- curve A corresponds to a solution saturated with (oxygen in) air at atmospheric pressure
- curve B to a solution containing exactly one-tenth as much oxygen
- curve C to an oxygen-free solution.

The electrodes used were a saturated calomel reference and an indicator of rotating platinum wire approximately 4 mm long and 0.5 mm in diam. According to usual polarographic convention, cath-

odic current at the indicator electrode (i.e., current flowing when reduction is occurring at the indicator electrode) is plotted above the origin and anodic current (i.e., current flowing when oxidation is occurring at the indicator electrode) is plotted below the origin. Applied potentials for which the indicator electrode is negative with respect to the saturated calomel electrode are plotted to the right of the origin and potentials for which it is positive to the left.

It may be seen in Figure 1 that the current passing through the electrolysis cell is essentially zero for all applied potentials between plus 0.9 and minus 0.1 volt. No current flows because there is no molecule or ion in the solution which can be either oxidized or reduced within this potential range. In this range the indicating electrode is polarized; that is, the current is substantially independent of the applied voltage. But when the indicator-electrode potential is made more positive than plus 0.9 volt, the solvent (water) oxidizes, and anodic currents are observed at the indicator electrode. When the indicator electrode is made more negative than minus 0.1 volt, reduction of oxygen becomes possible and cathodic currents are observed at the indicator electrode.

At an applied potential of minus 0.2 volt, the rate of the electrochemical reduction is slow. Only a small fraction of the oxygen molecules which reach the electrode is reduced; hence the currents are small. As the electrode potential is made more negative the electrochemical reaction rate becomes faster and the current increases rapidly. When the applied potential has reached minus 0.7 volt every oxygen molecule which reaches the electrode surface is immediately reduced and the electrochemical reaction rate becomes almost instantaneous. At this level the current is limited entirely by the rate at which oxygen molecules can diffuse from the solution body up to the electrode surface, and any further increase in the potential cannot cause the current to increase. For this reason the current plateau between minus 0.7 and minus 1.0 volt is called a diffusion current.

If all other factors remain constant, the rate at which oxygen molecules diffuse to the electrode surface (hence the magnitude of the diffusion current) is directly proportional to the solution's oxygen concentration. This proportionality forms the basis of quantitative polarography. If the applied potential is made more negative than minus 1.0 volt, reduction of the solvent becomes possible.

The diffusion-current magnitude depends not only on the concentration of the electroactive species, but on such factors as electrode size and shape, the diffusion coefficient of the electroactive species, and the hydrodynamic conditions prevailing in the solution. Normally, if all other factors remain constant, the diffusion current is directly proportional to the electrode area. The diffusion coefficient of any given solute is governed by the temperature and by the solution composition and viscosity; and the diffusion current, which depends upon it, is governed by the type of diffusion process involved (for example, square root of coefficient for spherical diffusion, and the first power of coefficient for finite plane diffusion). Since the temperature coefficient of diffusion coefficients is about 5 percent per deg C, diffusion currents usually increase by 2 to 5 percent per deg C, depending upon the specific substance and the type of diffusion involved.

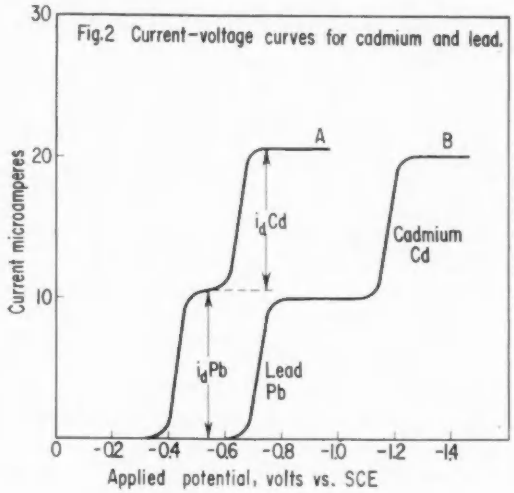
The nature and the thickness of the diffusion layer, hence the diffusion current, depends upon the flow solution in the neighborhood of the electrode. In general, more rapid stirring or higher flow rates produce larger diffusion currents.

Although a stationary electrode in a stirred solution yields reproducible hydrodynamic conditions and diffusion currents, they are more easily achieved by electrode rotation or vibration. Many different indicating electrodes are used in polarographic work. One popular type consists of a short length of wire, usually platinum, which is rotated or vibrated at a constant speed. A solid electrode cannot be used in a continuous analysis if the electrochemical reaction is one in which a solid is plated on its surface—plating changes electrode size and hence diffusion current magnitude, with time.

The active portion of a dropping mercury electrode is the drops of mercury which periodically form, grow, and fall from the tip of a fine-bore capillary at a constant rate of about one drop every 4 sec. This electrode is normally used in relatively quiet (unstirred) solutions, and has performed well in the laboratory. The growth and fall of the drops provide reproducible diffusion currents. The dropping mercury electrode may be used with flowing solutions provided flow rates are kept relatively small and care is taken to prevent turbulence.

The dropping electrode is constantly renewed during use, making it more versatile for continuous analysis than a solid electrode. The high hydrogen overvoltage of mercury permits the dropping mercury electrode to be used at potentials up to about minus 2.0 volts with respect to the SCE before reduction of water is encountered, while platinum, with a very low hydrogen overvoltage, cannot be used at potentials beyond about minus 1.0 volt. The exact limit in both cases depends upon the composition and the pH of the solution being analyzed. The mercury electrode cannot be used at positive potentials exceeding a few tenths of a volt, however, because of its anodic dissolution.

The membrane electrode, which shows considerable promise for continuous analysis, consists of a plane metallic electrode separated from the solution by a thin membrane through which the electroactive species must diffuse to reach the electrode surface. When used in a stirred or flowing solution, the diffusion gradient exists entirely in the membrane



itself. The diffusion current is independent of the stirring rate, provided the stirring rate is sufficient to maintain the electroactive-species concentration at the membrane's outside surface at the same value as in the solution's main body. Fundamental developmental work with electrodes of this type is still in progress, but there is little doubt that they will prove to be very useful.

When more than one electroactive species is present in the sample solution, each species has its own characteristic oxidation or reduction potential. Curve A in Figure 2 shows the current-voltage curve of 0.001 *M* lead ion and 0.001 *M* cadmium ion in oxygen-free 1.0 *M* potassium chloride solution. The potential at which an electrochemical reaction occurs is normally expressed as the half-wave potential—the potential at which the current is equal to one-half of the diffusion current. In Curve A of Figure 2 the half-wave potential of lead is minus 0.44 volt and cadmium minus 0.64 volt. The reductions of the two ions occur at potentials sufficiently separated so that identification of each electroactive species is possible. Lead concentration may be determined by a measurement of the ion diffusion current at about minus 0.54 volt, while cadmium concentration may be determined at minus 0.75 volt less the current at minus 0.54 volt.

The half-wave potential for an electrochemical oxidation or reduction depends upon electrolyte composition. The presence of complexing agents in particular has a pronounced influence on the half-wave potentials of inorganic ions. Curve B of Figure 2 shows the current-voltage curve for the reduction of lead and cadmium ions in 1.0 *M* potassium cyanide solution. Here, the half-wave potential is minus 0.72 volt for lead and minus 1.18 volt for cadmium. Both half-wave potentials are very different from those obtained in potassium chloride solution (Curve A), but the values of the diffusion currents are nearly the same, since the metal-ion concentrations have not been changed. (The small difference arises because the complexing agent changes the diffusion characteristic of the ions.) The half-wave potentials of organic molecules and ions usually depend upon the pH of the solution. By appropriate adjustment of the composition and pH of the solution it is usually possible to separate the half-wave potentials of several electroactive species in a sample so that the determination of each is possible.

AMPEROMETRIC ANALYSIS

The general procedure for applying polarography to continuous-process analysis is to impose a regulated voltage across the electrodes and then to measure the current. This is termed amperometric analysis. The applied voltage is that which gives the diffusion current of the species of interest. The measured diffusion current is proportional to species concentration. The applied voltage is changed to a new value for each species to be measured.

When the sample to be analyzed is a gas, it is frequently possible to employ a simplified type of polarographic cell. For example, Hersch has described a cell for the determination of oxygen. It consists of a central lead rod which is surrounded by a thin film of porous polyvinylchloride saturated with 5 *M* potassium hydroxide solution. This solution is surrounded with a fine-silver-wire gauze. The lead and silver electrodes are connected directly to a microammeter (or recorder) for measurement of the electrolysis current. The oxygen in the gas sample diffuses through the thin film of concentrated potassium hydroxide solution, which wets the silver gauze and is reduced at the electrodes. No external source of potential is required since the silver electrode is automatically maintained at the lead electrode's potential (about minus 0.8 volt vs. the SCE) to which it is connected through the microammeter. (A cell which requires no external source of potential is called an internal electrolysis cell. With the proper nonpolarizable reference electrode, the indicating electrode can be operated at any value.)

The electrolysis current is directly proportional to oxygen concentration in the gas stream provided no other reducible components are present and provided such other conditions as electrode size, flow rate and agitation, and temperature are properly adjusted and maintained at a constant value. Sensitivities of the order of 5 microamp per ppm of oxygen and response times of the order of 1 to 2 min are possible with this cell. It may also be used for the indirect determination of combustible gases such as hydrogen, carbon monoxide, or methane in oxygen-free samples by adding a known concentration of oxygen to the samples and then measuring the residual (excess oxygen after the mixture has been subjected to complete combustion).

POTENTIOMETRIC ANALYSIS

The potential of a reversible oxidation-reduction couple is a function of the ratio of the concentrations of oxidized and reduced forms. The relationship between potential and concentration is given by the Nernst equation:

$$E = E^{\circ} - \frac{RT}{nF} \ln \frac{(\mathrm{Red})}{(\mathrm{Ox})}$$

where E is the potential, E° is a constant (the standard potential), R is the gas constant, T is the absolute temperature, n is the number of electrons involved in the oxidation-reduction reaction, F is the faraday, (Red) is the concentration of the reduced form and (Ox) is the concentration of the oxidized form. For example, the potential of an inert electrode, such as platinum, dipping into a solution containing ferrous and ferric ions at room temperature, is given by:

$$E = E^{\circ} - 0.059 \log_{10} \frac{(Fe^{+2})}{(Fe^{+3})}$$

In principle, it is possible, by measuring the potential, to determine the $(Fe^{+2})/(Fe^{+3})$ ratio, or to determine either (Fe^{+2}) or (Fe^{+3}) if the other is known and constant and if the standard potential is known. However, several factors cause this method to be of very limited usefulness for the measurement of concentrations. In the example just cited, an error of only 1 mv in potential measurement would cause an error of about 4 percent in the determination of concentration. It is only in rare situations that potential measurements with a reliability of even plus or minus 1 mv can be realized. Reasons include poisoning of the indicating electrode, changes in the value of the standard potential, changes in temperature, failure of the system to reach equilibrium in a reasonable time, and the possible presence of other oxidation-reduction couples.

While the potentiometric method is poorly suited to precision analysis it is useful for indicating the order of magnitude of concentrations, and in this application can be used over extremely wide ranges. The measurement and recording of pH (hydrogen-ion concentration) is one such application.

An example of the use of the potentiometric method in continuous-process analysis is the Davis Emergency Equipment Co.'s oxygen analyzer, Figure 3. A gas sample containing parts per million of oxygen is bubbled into an ammonical solution of cuprous ammonium chloride. The oxygen reacts with the cuprous ions to form cupric ions:

$$2\,Cu(NH_3)^{2+} + 4\,NH_4OH + 1/2\,O_2 \rightarrow 2\,Cu(NH_3)^{4++} + 2\,OH^- + 3\,H_2O$$

Two carbon electrodes are located in the liquid stream, one measuring $(Cu^+)/(Cu^{++})$ before the reaction takes place, and the other electrode measuring the same ratio after reaction occurs. The emf generated between the electrodes and measured by a potentiometer is therefore a function of O_2 concentration.

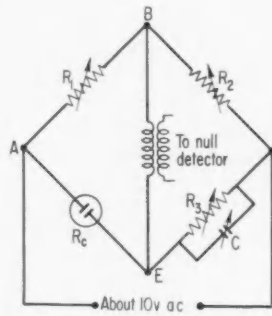
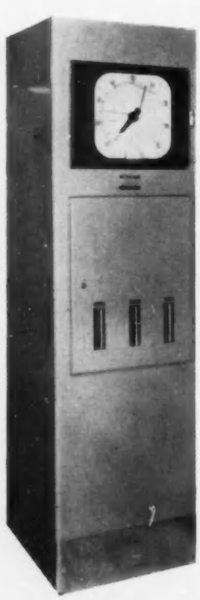


FIG. 4
Basic ac Wheatstone bridge for making conductance measurements



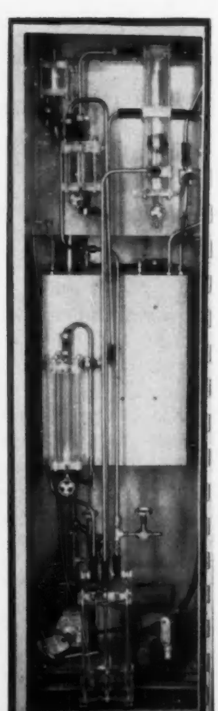


FIG. 3. Davis Instrument oxygen analyzer.

CONDUCTOMETRIC ANALYSIS

Electrical conductance measurement of electrolyte solutions has been widely exploited as a means of analysis. Such measurements are normally made with an ac Wheatstone bridge, Figure 4. Here, R_1, R_2, and R_3 are variable resistances, C is a variable capacitance, and R_c is the cell with its two electrodes, usually platinized platinum, dipping into the solution to be examined. A sine wave alternating voltage of 1,000 to 10,000 cps at about 10 volts is applied to terminals A and D. A null detector is connected across B and E. When the bridge is nulled, the dial readings indicate the resistance, or conductance, due to the total ions present in the solution.

Under the conditions above, the impedance of R_c can be made completely resistive. That is, the

double-layer capacity at each electrode can be made large so that its reactance at these frequencies becomes negligible compared to the solution resistance between electrodes. Then, as a rule, electrochemical reactions will not occur at the electrodes—the voltage does not become large enough. Hence, the current is limited not by the diffusion of electroactive species but by the total resistance of the solution, which is a function of all ions present.

Although limited to electrolytes, the method is capable of high precision. Accuracies of plus or minus 0.1 percent are readily achieved, and by differential measurements and thermistor temperature compensation this limit may be reduced to about plus or minus 0.03 percent. The method is insensitive to variations in flow rate, and long-term stability is excellent. In some cases it is possible to determine nonconducting species by some type of indirect method. For example, nonconducting organic chlorine compounds in steam condensates have been determined by sample vaporization and thermal pyrolysis, which convert the organic chloride to hydrochloric acid. Conductance measurements on the condensate from the pyrolysis unit follow.

The most serious drawback to the conductometric method is its lack of specificity. Since all of the ions in solution contribute to the conductance, the method can be employed in its simple form only for solutions containing a single electrolyte or for solutions in which the concentrations of all electrolytes save the one to be determined remain constant. By measuring the conductance of a sample solution before and after the addition of suitable reagents, a high degree of selectivity is possible.

An example of a continuous process analyzer utilizing conductivity is the A. O. Beckman dissolved oxygen analyzer. This analyzer measures parts per billion of dissolved oxygen in a liquid stream by a differential conductivity measurement. Conductivity is measured before and after the addition of gaseous nitric oxide, which reacts with the oxygen to form nitrous acid, thus increasing conductivity. The difference in conductivity is a measure of the dissolved oxygen.

A recent development in conductometric analysis is the use of high-frequency alternating voltages of megacycles per second. The sample cell is placed in the tank circuit of an oscillator, and changes in solution composition produce changes in the frequency or in the grid, plate, or cathode currents and voltages. This method, though nonspecific, has this advantage: the electrodes need not be in the solution but may be on the outside of the cell.

TITRIMETRIC ANALYSIS

A titrimetric analysis measures the amount of reagent required to cause a quantitative conversion of some constituent in the sample to a different compound. Although titrimetry is one of the oldest and most highly developed methods of laboratory analysis, this technique has so far been used very little in continuous process analysis. The apparatus necessary for a continuous titrimetric analysis consists of a metering device for adding sample to a reaction vessel at a constant rate, a pump for delivering the reagent to the reaction vessel, some type of sensing system in the reaction vessel to indicate whether sufficient reagent has been added, and some

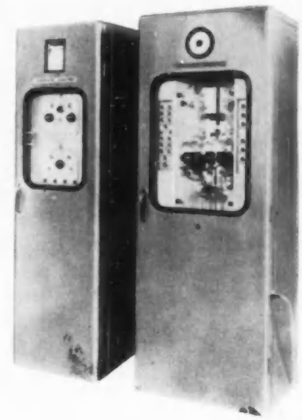


FIG. 5. Fielden Instrument's Titromatic Analyzer.

type of control mechanism, which operates from the output of the sensing system to adjust the rate of reagent delivery to that value just sufficient to react quantitatively with the sample. If the rate of sample delivery and the reagent concentration are maintained constant, the delivery rate of the reagent (titrant) is then directly proportional to the concentration of the solution components being titrated. Figure 5 shows the Titromatic Analyser developed in England by Electronic Instruments, Ltd. and Imperial Chemical Industries, and now distributed in the U. S. by the Instrument Div. of Robertshaw-Fulton Controls Co.

The versatile titrimetric method offers several advantages which make it attractive for continuous analysis. Probably more compounds, both organic and inorganic, can be determined by this method than by any other. By proper selection of titrant and reaction conditions, the method can be made highly specific, thus permitting the determination of individual components or single types of compounds in complex mixtures. Titrimetry can be used over wide concentration ranges; under proper conditions accuracies of plus or minus 0.1 to 1.0 percent can be readily achieved. If the sample delivery lines are kept short, the response of a titrimetric instrument to changes in concentration is very rapid. The most serious drawbacks of the method are the necessity for preparing and storing the relatively large volumes of standard solutions of the reagent and the difficulties encountered with the controlled-volume pumps delivering the sample

and reagent. But these drawbacks are no more serious than those encountered in many other methods which now enjoy much greater popularity.

The heart of any titrimetric analyzer is the indication or sensing system which monitors the sample-reagent mixture and controls the rate of reagent delivery to maintain this mixture at equivalence. Photometric, conductometric, and thermometric techniques may be used to instrument this system, but they are not as good for continuous analysis as the electrochemical methods of potentiometry and amperometry. In any case, the optimum method for end-point detection can be readily deduced from the current-voltage curves for each titration system.

COULOMETRIC ANALYSIS

An amperometric analysis method becomes a coulometric method if conditions are adjusted so that the electroactive species are quantitatively oxidized or reduced during the measurement process. A coulometric analysis may be defined as the process of measuring the quantity of electricity (coulombs) required to quantitatively transform the substance to be determined into some new substance by electrochemical reaction. The electrochemical reaction must proceed with 100-percent current efficiency. The quantity of electricity required is directly proportional to the quantity of substance present in the sample, that is, to the concentration-sample volume product:

$$Q = FVC$$

where Q is coulombs, F is the faraday (96,500 coulombs per equivalent), C is the concentration in equivalents per liter, and V is the sample volume in liters. For a continuous process this becomes:

$$\frac{Q}{t} = \frac{FVC}{t} \text{ or } i = FvC$$

where i is the current in amperes (coulombs per sec) and v is rate of sample flow (liters per second) into the analysis apparatus. Hence, if the sample flow rate is maintained constant and the electrochemical reaction is quantitative, the electrolysis current is directly proportional to the concentration of the substance being determined.

So far as the authors know, the only reported continuous coulometric methods involving the direct oxidation or reduction of the desired constituent are those for the determination of oxygen and of water. If a long Hersch cell like the one described previously is placed in a pipe of internal diameter only slightly larger than the cell's external diameter, and if the sample is passed through this pipe at a sufficiently small flow rate, all oxygen in the sample will diffuse to the silver electrode and be reduced as the sample passes through the narrow annular opening between the cell and the pipe. Since the quantity being measured is the number of coulombs per sec required to quantitatively reduce all oxygen in the sample, the method is a coulometric analysis. The electrolysis current is directly proportional to the product of the concentration of oxygen times the flow rate, and is independent of factors such as temperature, electrode area, thickness of the solution film on the electrode, turbulence, etc., which affect the rate at which oxygen diffuses to the electrode surface—provided, of course, that none of these factors changes to such an extent as to cause nonquantitative reduction of the oxygen. In the coulometric method, only the sample flow rate need be carefully controlled to make the current directly proportional to oxygen concentration.

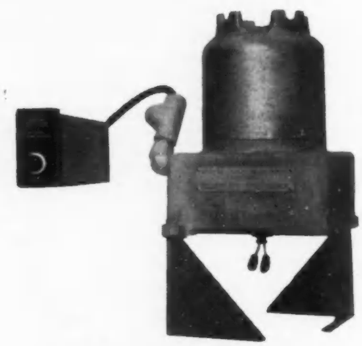


FIG. 6. Consolidated Electrodynamics Corp.'s moisture monitor, based on du Pont development, for continuous in-plant moisture measurement of process streams. Range: 1 to 1,000 ppm.

The du Pont water analyzer is another example of an instrument which is coulometric in nature. Figure 6 shows one commercial version. The cell of this analyzer contains two spirally-wound platinum electrodes—covered with a film of partially hydrated phosphorous pentoxide—in a capillary tube. In passing through the tube, all water is absorbed and quantitatively converted to hydrogen and oxygen:

Cathode reaction	$4H_2O + 4e- \rightarrow 2H_2 + 4OH^-$
Anode reaction	$2H_2O \rightarrow O_2 + 4H+ + 4e-$
Overall reaction	$2H_2O \rightarrow 2H_2 + O_2$

These relationships show that 4 faradays, or $4 \times$ 96,500 coulombs of electricity, are required for converting two gram moles of water to hydrogen and oxygen. For a sample flow rate of 100 ml per min, this corresponds to a sensitivity of 13.2 microamp per ppm of water in the gas sample.

There is no reason why many other determinations cannot be made in a similar manner. It should be possible, for example, to determine lead and cadmium in a cyanide medium. If a sample containing these two metal ions were passed through a suitable cell in which the cathode was maintained at about minus 0.95 volt vs. SCE, lead ion would be deposited as rapidly as it reached the cathode (see the current-voltage curve in Figure 2). If the cell design were such that all lead in the sample

solution could reach the electrode during passage through the cell, reduction would be quantitative. If the sample flow rate were maintained constant, the electrolysis current would be proportional to the concentration of lead in the sample. And if the effluent from this cell were passed through a similar cell in which the cathode was maintained at about minus 1.5 volts, cadmium could be determined from the electrolysis current in this cell. (Obviously, cadmium alone could not be determined without prior removal of the lead, since lead and cadmium are simultaneously reduced at minus 1.4 volts; the electrolysis current in this case would give the sum of cadmium and lead.) In principle most of the systems which accommodate the polarographic method are amenable also to analysis by the coulometric method, although it is difficult to design an electrolysis cell for quantitative electrolysis, particularly if a fast response to changes in concentration is desired.

This design difficulty can be considerably reduced in many cases by an indirect method. Consider the problem of determining ferrous ion in a sample. If the coulometric method were employed, it would be necessary to control the working electrode's potential so that the ferrous ion striking the electrode would be oxidized to the ferric state. The potential selected would have to be one at which no other sample component would undergo an electrochemical reaction. And it would be necessary to operate the cell so that all of the ferrous ions would reach the electrode and be oxidized.

If a large excess of cerous ion (which does not react with ferrous ion) were added to the sample and if a current in excess of the diffusion ion current of the ferrous ion were passed through the cell, both the ferrous and cerous ions would be oxidized at the working electrode. The oxidation product of cerous ion, ceric ion, reacts rapidly and quantitatively with ferrous ion, oxidizing it to the ferric state. These reactions are symbolized:

$$\left.\begin{array}{ll} 1. & Fe^{+2} \longrightarrow Fe^{+3} + e^- \\ 2. & Ce^{+3} \longrightarrow Ce^{+4} + e^- \end{array}\right\} \text{Reactions occurring at the electrode surface}$$

$$3.\ Ce^{+4} + Fe^{+2} \rightarrow Ce^{+3} + Fe^{+3} \quad \text{Reaction occurring in the body of the solution}$$

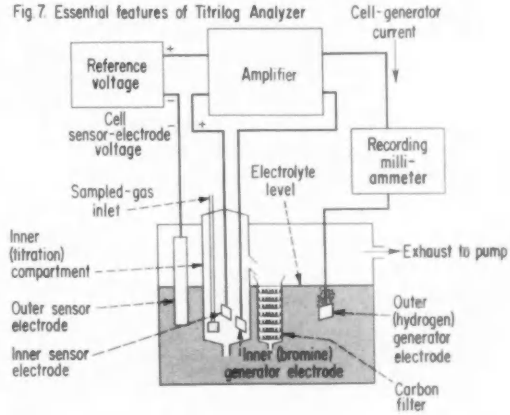
$$2. + 3.\quad Fe^{+2} \rightarrow Fe^{+3} + e^-$$

Since the sum of reactions 2 and 3 equals the desired electrochemical reaction, no error is introduced by adding the cerous ion to the sample. The intermediate cerium oxidation-reduction system permits the ferrous ion to be quantitatively oxidized away from the electrode surface. This opens the way to simpler cell designs and faster response times.

This kind of secondary coulometric process differs only slightly from a conventional titration employing standard solutions of reagents. In the latter the reagent is generated *in situ* by an electrochemical process instead of being prepared as a standard solution, and the measurement involved is that of the quantity of electricity per unit time instead of the volume of standard reagent per unit time. A coulometric titration method, like any other titration method, requires some suitable end-point sensing system which, through an appropriate control device, maintains the electrolysis current at such a value that no ferrous ion remains unoxidized and no excess ceric ion is generated.

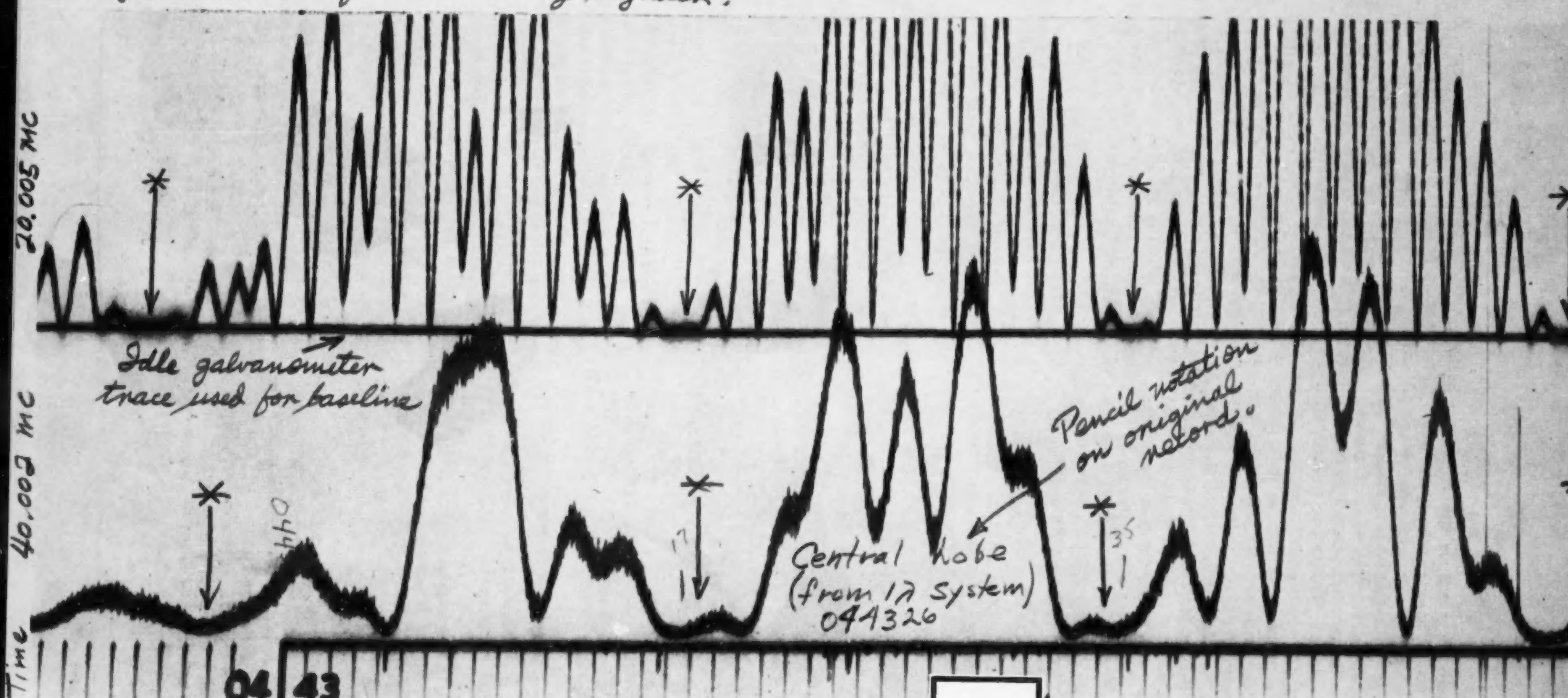
By means of the coulometric titration method, it is frequently possible to determine substances which are themselves not electroactive and which cannot be determined by direct coulometry. For example, it is possible to determine hydrogen sulfide coulometrically by using electrolytically generated bromine. A continuous analysis instrument, called the Titrilog, which is specifically designed for this and other similar determinations, is manufactured by Consolidated Electrodynamics Corp.

Fig. 7. Essential features of Titrilog Analyzer



The essential features of this instrument are shown in Figure 7. The amplifier's output current is utilized as the electrolysis current. Bromine is generated in the inner compartment of the titration cell, while hydrogen is generated in the outer compartment and is washed to exhaust. The bromine produces a voltage across the two sensor electrodes which changes in magnitude and polarity depending on bromine concentration. A fixed reference voltage opposes the sensor voltage, and their difference causes the amplifier output to change. When a reactive gas, such as hydrogen sulfide, is admitted to the cell, the bromine concentration decreases, causing a drop in sensor voltage. The amplifier input voltage then increases and the amplifier responds to increase the rate of bromine generation. Equilibrium is reached when the new rate satisfies the demands of the reaction, and maintains the desired residual bromine concentration corresponding to the set-reference voltage. When the sample flow rate is maintained constant, the generation current is directly proportional to the concentration of the reactive component in the sample stream.

#2 This picture shows slightly less than one minute of a record perhaps 10 minutes long. It is a good interferometer record, though not quite as "pretty as #1. It has a very good record of WWV timing signals.



Timing "ticks" (seconds) from WW[illegible]
* - Nulls in pattern of interferometer antenna [illegible]. The other lobes & nulls (fine structure) are signal fading.

Burning Control for Cement Kilns

M. C. SUTTON
LEWIS A. PARSONS
Calaveras Cement Co.

In the last few years cement kilns have used combustion control based on continuous analysis of the gases leaving the kiln for oxygen and combustibles. The oxygen recorder-controller varies draft-fan speed to control the amount of secondary air entering the kiln, and thereby maintains a constant oxygen (and excess air) content in the exit gases. Some kilns have used ratio control between the fuel setting and the fan speed to maintain the excess-air ratio constant even when fuel setting is changed.

It is more difficult to control the heat transferred to the "mix", a finely divided and properly proportioned mixture of calcareous (limestone) and argillaceous (shale or clay) materials. The kiln operator—the "burner" in cement parlance—normally has no way of knowing how this is progressing until he is able to see the material from the firing end of the kiln, usually a distance of 50 to 60 ft. Until recently he has had to rely on the exit gas temperature. But for some kilns exit temperatures must be as high as 900 deg F, greater than that necessary to evaporate the water in the slurry at the feed end. Furthermore, they simply indicate that enough heat transfer is taking place in the center of the kiln.

A thermocouple placed near the center of the kiln, first to record the temperature of the mix to guide the burner, and later, after proper standards are established, to control the fuel automatically to maintain the optimum temperature, could give far better control. But thermocouples that project through the brick fluctuate in temperature between that of the gas and the mix, and the results are thus erratic. Also, the temperature rises as the brick erodes.

To express this in greater detail, "E" kiln is 360 ft long and 11.25 ft in diameter, with a diameter of 10.25 ft inside of the bricking. The kiln rotates at approximately 1¼ rpm and has a slope of $\frac{7}{16}$ in. per ft, which gives a material residence time of about 2 hours in the kiln. Natural gas is used as fuel. The mix has a calculated depth of from 11 to 15 in. in the bottom of the kiln, and makes contact with 68 to 80 deg of the circumference. A thermocouple protruding through the brick would be in contact with the material less than a quarter of the time and in contact with combustion gases at a much greater temperature the rest of the time.

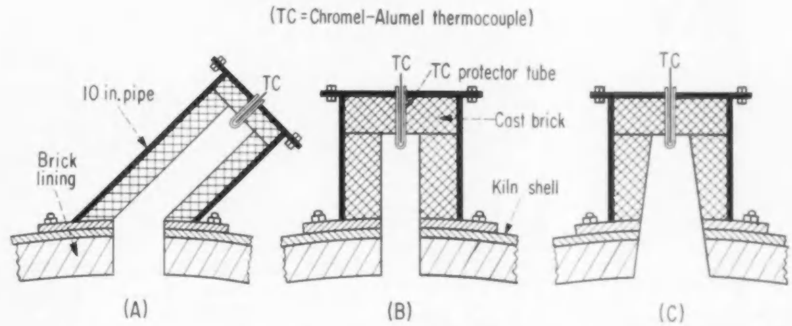


FIG. 2. Thermocouple well and collector rings on outside of cement kiln.

In a kiln study begun seven years ago, and still in progress, material has been drawn from a kiln through ports in the shell, into an insulated container with a thermocouple in the bottom. It was decided to attach such a well to the kiln so that it would fill at the lower part of the rotation and empty at the upper part. These wells are formed by casting Chromastic compound inside of a 10-in. pipe. Various types of wells were tried.

The inclined well, Figure 1A, was designed to retain the material load in contact with the thermocouple as long as possible.

The second type, Figure 1B, was installed in a position normal to the kiln shell and was made shallower. This obtained satisfactory mix temperatures as long as it emptied freely, but it had a tendency to plug.

The third type, Figure 1C, installed still later, has been working satisfactorily in all respects for about a year.

When these experiments began it was thought necessary to immerse the thermocouple in solid material continuously; so three wells were used. Later one well was found to be enough. It is located about 170 ft from the firing end and a Chromel-Alumel thermocouple with a stainless steel protector records average temperatures of 1,400 deg F.

The thermocouple is connected to two phosphor-bronze collecting rings (see Figure 2) mounted around the kiln on insulating blocks, with springs to compensate for thermal expansion.

The thermocouple signal goes to a temperature recorder-controller which controls the fuel valve to maintain constant material temperature at the thermocouple. Any shift in the optimum temperature at the control point causes an immediate response in the fuel flow, accompanied by a proportional change in the air. Substantial gains in burning efficiency and quality are being realized.

FIG. 2. Thermocouple well and collector rings on outside of cement kiln.

Servos Test Servo Components

FIG. 1. Synchro plugs into automatic tester as shown, and cable is attached to its terminals. Holder is changed for different size synchros.

ROBERT KELLY
Kearfott Co., Inc.

Military acceptance tests for synchros take a mean time of nearly half an hour per synchro when conventional manual testing procedures are used. Many thousands of synchros are produced each month, so the development of automatic testing equipment to reduce time and produce permanent records is easily justified.

This tester is unique in that it produces a permanent, analog, punched-card record directly from the positions of its measuring servos. Another useful, if not particularly unique, idea is that only four servos measure and record seven synchro parameters.

The measuring circuits for each of the seven parameters (angle error, open-circuit current and power, transformation ratio and phase, and fundamental and rms null voltages) are arranged to produce an electrical null. A servomechanism automatically finds this null in each case, and simultaneously positions a punch with respect to a scale printed on the output card. No direct indication is made.

After each measurement is completed and the card is punched, an operation sequencer makes the connections programmed for the next test. The tester is sequenced by the completion of the previous test, rather than by time, because null time for each servo is variable and delays would result if each step were long enough to include the longest.

As stated above, the output card is the only indication of test results. The meter seen in the photograph of Figure 1 is used by the operator only to null the electrical zero after plugging in the synchro and before starting the automatic test cycle.

There are three card punches, arranged as shown in Figure 2. The card of Figure 3 is inserted in the machine at the top, as shown in Figure 1. After the electrical zero is set and servo 1 positions punch 1 to zero error, the start button is pressed. Punch 1 then records a zero angle error at electrical zero. At the same time punch 2 is positioned on the scale marked "A" and records the value of open-circuit rotor current (stator open), and punch 3 records the open-circuit power on the scale "W". Both recordings are percentages of maximum values.

Angle error is measured (in minutes of arc) by the proportional-voltage-nulling method, which compares the rotor's mechanical and electrical positions. The electrical position is from two 10,000-ohm resistors and a 10,000 ohm noninductive decade voltage divider connected in delta across the output terminals S1, S2, and S3 of the synchro under test. This delta reference is attached mechanically to an index plate which rotates the rotor of the synchro in 5-deg steps (within 15 sec. of arc) and also moves the wiper of the delta reference.

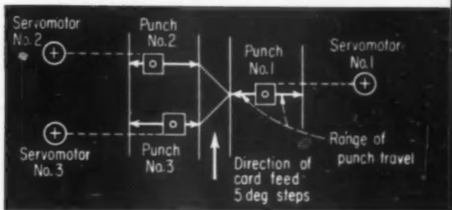


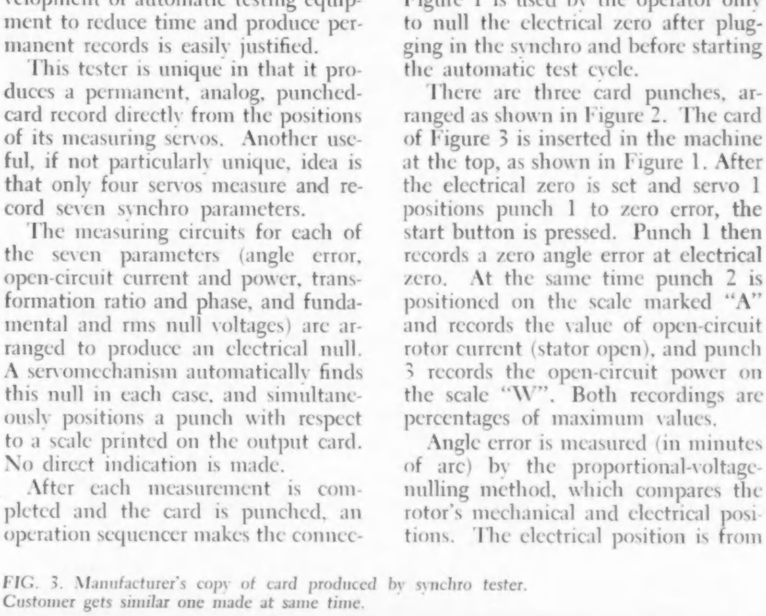
FIG. 2. Three punches, arranged like this, permanently mark the scales printed on the card in Figure 3.

Thus, if an error occurs at any 5-deg interval it appears as a voltage at the wiper of the delta reference. This error voltage causes servo 1 to move the index plate and rotor to null, and to move punch 1 to the proper error indication. The null relay then transfers the fixed-phase power from the driving servomotor to punch 1.

The circuit used to measure angle error is shown in Figure 4. If control transformer or differential transmitter synchros are tested, an additional voltage source is needed to energize the stator of the synchro. The plug-in signal generator (boxed in Figure 4) contains a synchro control transmitter which is connected in parallel with the delta reference and the stator of the unit under test. After the control transmitter is nulled it is locked at null by removing the fixed phase from servo 4 in the signal generator.

Angle error is recorded at each 5-deg

FIG. 3. Manufacturer's copy of card produced by synchro tester. Customer gets similar one made at same time.



interval. At 30 deg from electrical zero punch 2 records the percentage error in transformation ratio "T" from nominal, and punch 3 records the phase shift error "ϕ" in degress from nominal. At every 60 deg. punch 2 records the rms null voltage, and punch 3 the fundamental null voltage, as percentage of maximum values.

Punched cards like those produced by the synchro tester are good permanent records. Actually, three cards are punched simultaneously. The accuracy of the tester is shown by the card reproduced in Figure 3, which was passed through twice to test its repeatability.

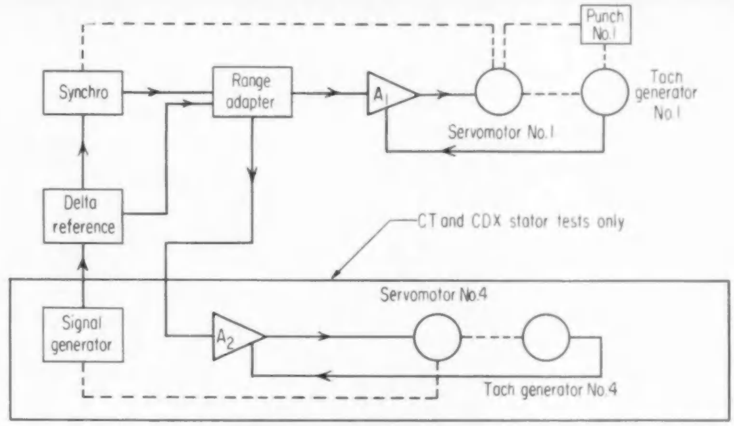


FIG. 4. Circuit for measuring angle error is typical of way servos are used to measure parameters and position card punches.

Hydraulic Servos for Function Generation?

E. KENNELLY and R. KOPP
Grumman Aircraft Engineering Corp.

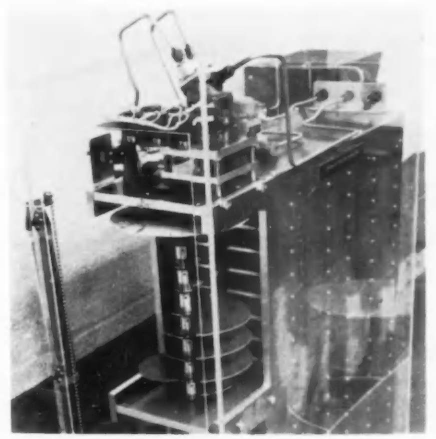


FIG. 1. Hydraulic servo drives nonlinear cams to position linear motion pots in this unusual function generator.

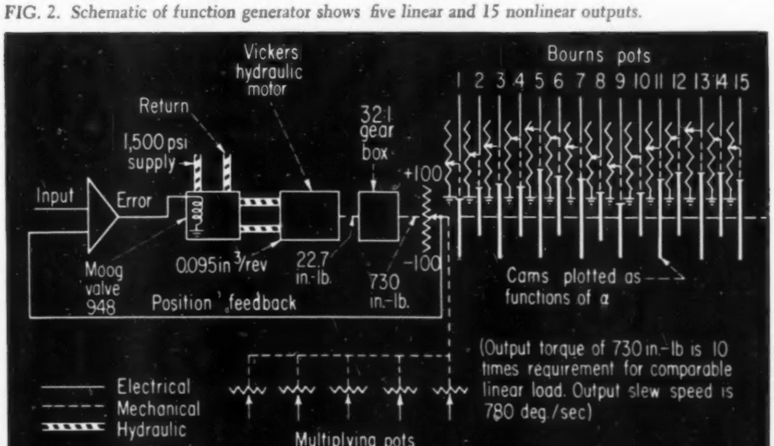
Early flight simulators for conventional aircraft had three degrees of freedom and used relatively little analog computing equipment. A good-enough simulator for supersonic aircraft, however, needs five degrees of freedom because roll divergence problems become very critical. This means a lot of analog equipment, and airplane development time schedules do not permit waiting out the delivery time. The decision at Grumman was to design and build some special computing equipment.

For one problem in particular, it was seen that much computing equipment could be saved by building a generator for the 11 nonlinear functions of angle of attack which appeared in the equations of motion.

The design decided upon uses a system of cams and cam followers to drive Bourns linear-motion potentiometers. The cam shapes represent the functions plotted in polar coordinates and scaled such that 1 deg of angle of attack is equal to 10 deg of rotation. A voltage proportional to the cam follower's movement, and thus proportional to the function, is available on the potentiometer. These functions can be multiplied by other variables simply by applying a voltage across the potentiometer proportional to the variable.

A high-speed servo system was needed to drive the large nonlinear load imposed by the cams, and a hydraulic servo was considered the best way to get sufficient driving torque with the large torque-to-inertia ratio. The servo had to have: 1) a response of one cycle per second at amplitudes of 30 to 40 deg with a maximum phase shift of 2 deg; 2) a static nulling accuracy and linearity of plus or minus 0.5 deg; and 3) a slew speed of 500 deg per sec. The final design is shown in Figure 2. No stabilizing networks were needed because of the large torque output and high torque-to-inertia ratio of the hydraulic motor. The function generator has an essentially flat frequency response to 5 cps.

FIG. 2. Schematic of function generator shows five linear and 15 nonlinear outputs.



Much of the original work on the function generator was done by Robert Kress of the Grumman Research Dept.

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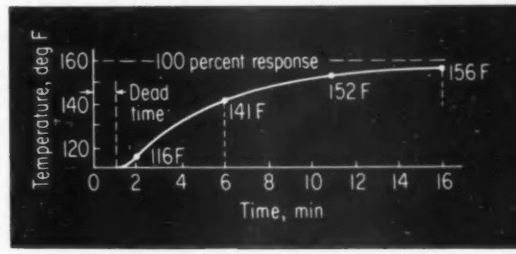


FIG. 1. Water temperature rise following a step change in steam input to a water heater.

PROBLEM: Modify a commercially available three-mode (proportional-reset-rate) controller so that it will more precisely and rapidly control a process in which the transportation lag (dead time) is nearly as long as the major transfer lag.

SOLUTION: Add additional lags to the standard single lag of the controller reset loop. The closer matching of process dynamics by the dynamics of the modified reset loop provides a retarded reset action that accommodates a tighter gain (narrower proportional band).

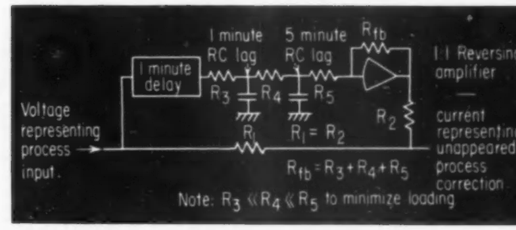


FIG. 2. Optimum electronic memory section for control of water heater with response shown in Figure 1.

L. D. KLEISS
Phillips Petroleum Co.

Even with rate action, the performance of commercially available controllers deteriorates when they are applied to processes in which the response dead time approaches the value of the longest transfer lag.

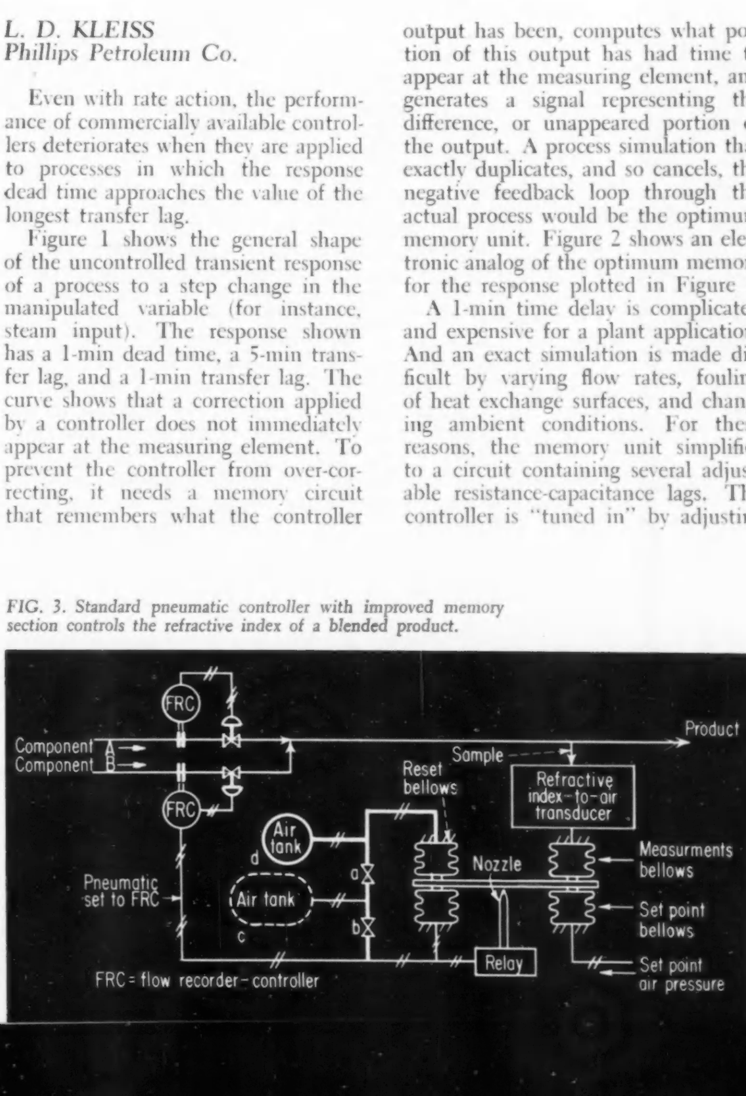
Figure 1 shows the general shape of the uncontrolled transient response of a process to a step change in the manipulated variable (for instance, steam input). The response shown has a 1-min dead time, a 5-min transfer lag, and a 1-min transfer lag. The curve shows that a correction applied by a controller does not immediately appear at the measuring element. To prevent the controller from over-correcting, it needs a memory circuit that remembers what the controller output has been, computes what portion of this output has had time to appear at the measuring element, and generates a signal representing the difference, or unappeared portion of the output. A process simulation that exactly duplicates, and so cancels, the negative feedback loop through the actual process would be the optimum memory unit. Figure 2 shows an electronic analog of the optimum memory for the response plotted in Figure 1.

A 1-min time delay is complicated and expensive for a plant application. And an exact simulation is made difficult by varying flow rates, fouling of heat exchange surfaces, and changing ambient conditions. For these reasons, the memory unit simplifies to a circuit containing several adjustable resistance-capacitance lags. The controller is "tuned in" by adjusting these lags for the closest approximation to the process dynamics. A graphical analysis of the process response, in a range of normal operating conditions, provides the data on process dynamics.

A controller with the required positive feedback path was modified for improved control of a blending process with a long dead time. Figure 3 shows a cascaded control system for blending two components to produce a product with a desired refractive index. The system has a 1-min dead time due to flow in mixing and sample lines and to the flushing time of the refractive index cell. Rate action was not used because of its sensitivity to flow noise. When a controller with reset action failed to acceptably control refractive index, the reset feedback path (shown in heavy lines) was altered by adding a second RC lag composed of a restriction and a tank (dotted lines).

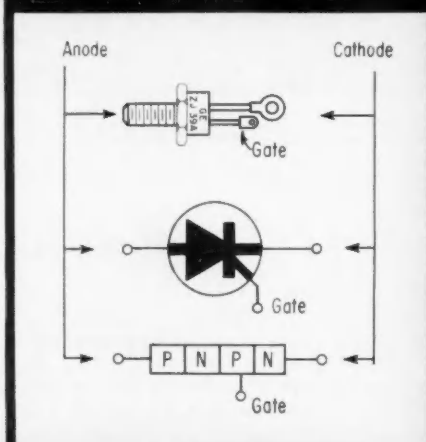
The use of more RC lags would mean better simulation of the dead time, but improved simulation per lag falls off rapidly after two lags. In a series of RC lags, each succeeding air restriction should offer progressively greater flow restriction to minimize the effect of loading by downstream RC stages. Air tanks will usually be smaller in succeeding stages. In Figure 3, for example, valve *a* is open wider than valve *b* and tank *c* is larger than tank *d*.

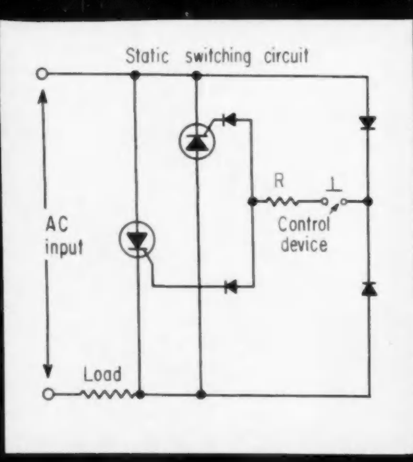
FIG. 3. Standard pneumatic controller with improved memory section controls the refractive index of a blended product.



NEW PRODUCTS

LISTING IN GROUPS





NEW RECTIFIER has control gate.

Top drawing left shows a ¾-size sketch and two schematic representations of a new silicon controlled rectifier, the Type ZJ-39A. Combining some of the features of both a transistor and a rectifier, it consists of a p-n-p-n semiconductor with three rectifying junctions. A third lead, called the gate, is in ohmic contact with the center "p" region. Applying an appropriate signal to this third lead causes an avalanche breakdown of the center junction. After breakdown, voltage across the device drops to about 1.25 vdc max so that current through it is determined primarily by the load it feeds.

The controlled rectifier operates somewhat like a gas thyratron. In both devices the conduction cycle is controlled by power applied to a third terminal, and both will continue to conduct until the anode voltage is either removed or reversed. In the thyratron, however, firing power is generally applied as positive grid-to-cathode *voltage*, whereas in the controlled rectifier this power is applied as positive gate-to-cathode *current*. To maintain forward conduction, a minimum holding current of 10 ma is required.

Some of the advantages of this new device over thyratrons are a very low forward voltage drop, faster firing and recovery times, higher efficiency, absence of a filament with its attendant warm-up delay, and a better operating temperature range. As in other semiconductor devices, rated peak inverse voltage and specified load currents should not be exceeded. Since the new device does not include its own heat sink, it must be mounted on a generous-sized cooling fin for high temperature operation.

A few of its more obvious applications are the replacement of relays, thyratrons, power transistors, and conventional rectifiers of all types in circuits designed for static switching, dc motor control, power regulation, dc-to-dc conversion, etc.

The circuit diagram for one such application is shown here. This circuit is designed to provide high-speed switching of power loads where a high duty cycle is involved. The control device indicated might consist of the contacts of a thermostat, pressure switch, or current relay. Signals from magnetic cores, transistors, or tubes can also be used to control sizable blocks of power. Resistor R is provided to limit gate current. The two diodes act to prevent any damage due to reverse gate current.

Variations of this circuit might be used with conventional dc power supplies to provide both switching and rectification with the same device. With the contacts of a sensitive current relay in series with the gate current, such a circuit could interrupt fault currents in less than a half cycle.—General Electric Co., Syracuse, N. Y.

Circle No. 1 on reply card

SERVOMOTOR weighs less than 1 oz.

Small enough to pass through an engagement ring, this tiny servomotor measures only $\frac{1}{2}$ in. in diam by $1\frac{19}{64}$ in. long. Shown here about $1\frac{1}{3}$ times actual size, it is believed to be the smallest 400-cycle motor available for applications requiring instant response to input signals.

The subminiature motor consists of a squirrel-cage rotor on precision ball bearings, a two-phase stator, and a stainless-steel housing. Characteristics include: a fixed phase and control phase voltage of 26 volts: a fixed phase and control phase current of 92 ma; a power input of 3.3 watts; stall torque of 0.11 oz-in.; and an operating temperature range of minus 55 to plus 70 deg C.–Eclipse-Pioneer Div. of Bendix Aviation Corp., Teterboro, N. J.

Circle No. 2 on reply card

COMPACT CONVERTERS offer high speed.

Capable of speeds in excess of 500,000 conversions per sec, these new completely transistorized digital-to-voltage Multiverters generate a voltage equal to the product of a digital number and a fixed or varying reference voltage. If the reference is an ac voltage, the generated voltage is ac. If the reference is a fixed voltage, the Multiverters operate as conventional digital-to-voltage converters. Completely solid-state devices, their size can be as small as a pack of cigarettes; the smaller version in the photo has a volume of only 21 cu in. Accuracies to within 0.01 percent are available and, by sacrificing accuracy, conversion speeds up to 0.5 microsec are possible.—Packard-Bell Computer Corp., Los Angeles, Calif.

Circle No. 3 on reply card

NEW SWITCH features long life.

Pictured is one of a complete new line of motor-driven commutator switches. Typical applications include telemetering, sampling, and programming. Designed for a minimum life of 500 hours, these units are capable of switching high and low impedance circuits in aircraft and missile applications. A wide selection of poles and positions is available, with speeds ranging from $\frac{1}{8}$ to 30 rps. Available circuits provide either two or three independent switch sections per commutator, depending on the model. Drive motors operate on either 115 volts, 400 cps, or 26.5 vdc. Units maintain performance at temperatures of 85 deg C, with vibrations of 25 g's to 2,000 cps.—Pacific Div. of Bendix Aviation Corp., North Hollywood, Calif.

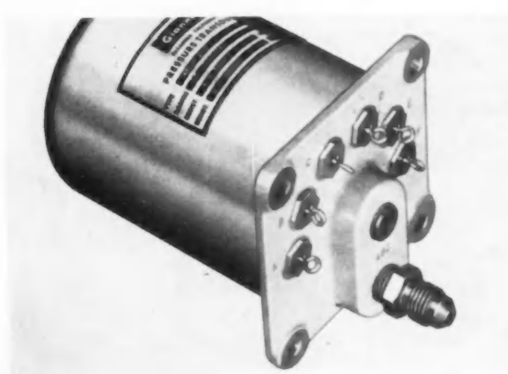
Circle No. 4 on reply card

PRESSURE TRANSDUCER meets rigid tests.

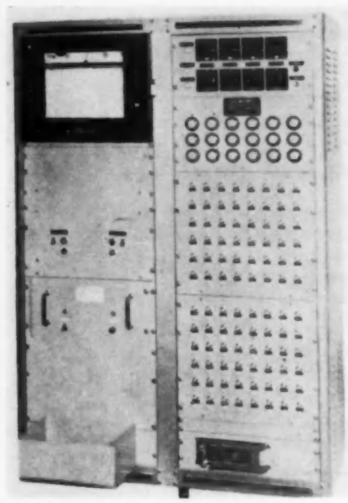
Accurate to within 1.0 percent of reading, this new pressure transducer features a 2,000-wire resolution and an ability to handle a variety of airborne applications. Units are available with pressure ranges from 0-10 through 0-50 psi.

One interesting current application is in a Machmeter transducer package, where the differential pressure has been cascaded between two units, providing an effective resolution of 4,000 wires over the entire pressure range. Accuracy is still within 1.0 percent. Other current applications include a Mach controller in a production missile, a variable-inlet control system for a jet, and a ratio measuring system.–G. M. Giannini & Co., Inc., Pasadena, Calif.

Circle No. 5 on reply card



RESEARCH, TEST & DEVELOPMENT



HIGH-SPEED PLOTTER

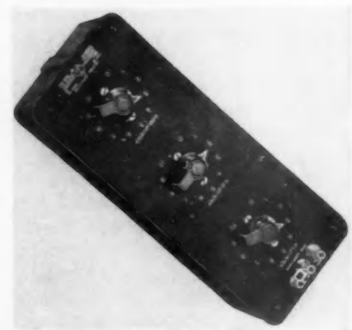
Designed for use with strain-gage inputs, the Gilmore Model 220 Plotter will scan and record four separate channels per second. Each channel is plotted on an individual graph while the test is in progress. Furnished as either a 48- or 96-channel unit, the Model 220 can accept two 60-500-ohm-resistance strain-gage inputs per channel. Ranges of 2,000, 5,000, and 10,000 microin. per 5½-in. graph are available with a gage factor adjustment of 1.6 to 2.2. Chart paper is installed as a continuous loop and may be rerun through the recorder several times, the number depending on the number of points in a given test.—Gilmore Industries, Inc., Cleveland, O.

Circle No. 6 on reply card

MULTIFUNCTIONAL

Available in either portable or rack-mounting versions, this new phase angle voltmeter can operate as a phase-sensitive null indicator, providing 10-microvolt sensitivity with less than 5 microvolts of noise. Harmonic rejection exceeds 55 db when used with internal filters. Nulling is accomplished at any phase angle by a convenient switch and calibrated phase shifter. The dual filter unit can also be used for the direct measurement of signal fundamental, phase angle, quadrature, and in-phase components. Twelve full-scale voltage ranges are available, from 1 mv to 300 volts.—North Atlantic Industries, Inc., Westbury, N.Y.

Circle No. 7 on reply card



DECADE CAPACITOR

The type 1419-K Decade Capacitor shown here features a maximum capacitance of 1.11 mf in steps of 0.001 mf. Dissipation factor of the new unit is said to be one-third that of older units and long-term stability of capacitance values is within 0.1 percent.—General Radio Co., Cambridge, Mass.

Circle No. 8 on reply card

CHECKS GEAR TRAINS

Shown is a new gear-train analyzer that provides accurate evaluation data on lost motion in precision gear trains used in servo systems, computers, etc. Basically, the analyzer consists of an electronic control unit and a two-phase torque actuator. The latter is substituted for the motor drive of the train to be checked. A dial on the control unit regulates voltage to the actuator, and a calibrated dial on the actuator

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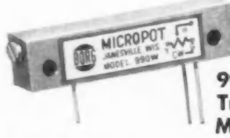
BORG MICROPOTS...
the Ultimate in Multi-Turn Precision Potentiometers

Borg offers a complete line of high-precision, linear potentiometers called MICROPOTS. Precision is Borg's business . . . that's why MICROPOTS offer so many exclusive advantages. Superior design and production methods make Borg MICROPOTS available in any quantity. Write today for the name of your nearest Borg Jobber or "Tech-Rep."

1100 Series MICROPOTS

A precision MICROPOT that offers your products a price advantage in today's competitive markets. Lug or lead type terminals. Accurate . . . dependable . . . long lived.

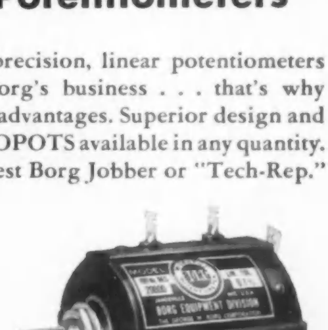


990 Series Trimming MICROPOTS

Small in size, lightweight, rugged and dependable. Three types of terminals . . . printed circuit, solder lugs or insulated wire leads.

900 Series MICROPOTS

Standard ten-turn and three-turn models to fit most special design needs. Extremely accurate and dependable under adverse environmental conditions including severe vibration and shock.



205 Series MICROPOTS

A quality MICROPOT. Designed for both military and commercial applications. Proven in many different mobile and stationary types of electronic circuitry.

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BORG EQUIPMENT DIVISION
THE GEORGE W. BORG CORPORATION
JANESVILLE, WISCONSIN

ELECTRONIC–MECHANICAL BORG EQUIPMENT

Built by Borg

MOTORS
MICROPOTS
MICRODIALS

NEW PRODUCTS

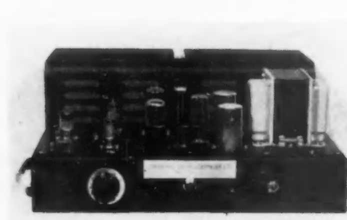
enables the inspector to read angular displacement of the actuator shaft during test. The instrument may also be used to measure the torque required to drive free-running gear boxes, and provides a means of setting gear-train safety clutches. It operates on a 115-volt, 6-cps supply.—Daco Instrument Co., Brooklyn, N.Y.

Circle No. 9 on reply card

FREQUENCY TIME COUNTER

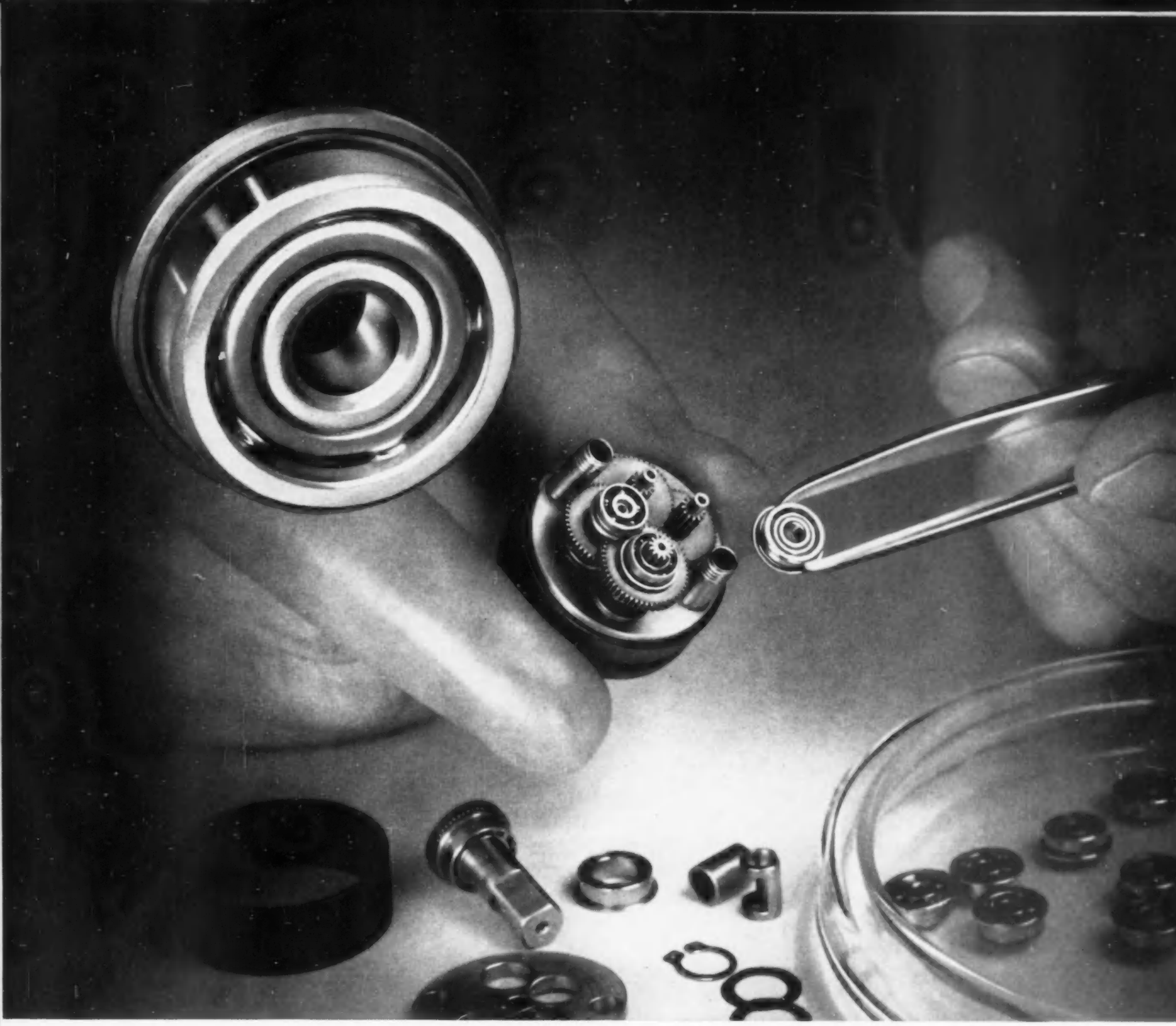
Completely transistorized, the Model 860 Frequency Time Counter contains the shaping, gating, switching, counting, and crystal-controlled time base circuitry required for counting, timing, frequency measuring, and interval generating functions. Features include the direct measurement of frequencies from 0 to 150 kc, frequency-ratio determination, period measurements for 1 or 10 cycles, and time-interval measurements for intervals from inputs up to 150 kc.—Potter Instrument Co., Inc., Plainville, N.Y.

Circle No. 10 on reply card



SERVO-AMPLIFIERS

Designed primarily for experimental work in instrument servomechanisms, this new electronic servo-amplifier requires only 115-volt, 60-cps power, yet operates well in 400-cps systems. Flexible enough for use in a variety



Barden Precision SFRI-5 miniature bearings as used in a computer gear train.

of breadboard applications, it will handle servomotors requiring up to 10 watts of control power. BuOrd Mk 8, and Mk14 motors, as well as many other popular types may be driven from the appropriate output tap points. Features include a calibrated gain dial, an input summation circuit, and provision for the insertion of stabilization and/or phase-shifting networks.—Dynamic Development Co., Westbury, N. Y.

Circle No. 11 on reply card

AUTOMATIC TESTER

Pictured is the new ALTREC, a system for the Automatic Life Testing and Recording of Electronic Components. This single instrument has facilities for environmental control and cycling as well as for periodic sequential sampling and measurement. A permanent printed record carries all data regarding the test and operating conditions. Measurements can be programmed at intervals of from 1 to 1,000 hours. The measuring device used consists of a digital voltmeter with automatic ranging.—Canadian Marconi Co., Outremont, Canada.

Circle No. 12 on reply card

NEW SERVO TESTER

Designed for automatic frequency-response measurements of servo systems, the Model 105-AR Servo Tester fits into a 19-in. relay rack. The instrument covers a data-frequency range of from 0.3 to 30 cps. Frequency can be set either manually by a front panel knob or remotely by some ex-

ternal dc voltage. Four suppressed-carrier 400-cps output voltages are available in two quadrature pairs. The data phase of the first pair is fixed, that of the second set on the front panel dial.—Industrial Control Co., Lindenhurst, N. J.

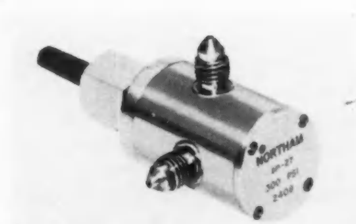
Circle No. 13 on reply card

MEASUREMENT & DATA TRANSMISSION

NEW PROXIMITY COIL

This new proximity coil uses an entirely nonmagnetic housing. Leads enter through a Bendix connector on top. Zinc and lead parts passing through the coil produce a phase shift to actuate a control relay and balance the system. Windings consist of two aiding primaries and two bucking secondaries. Sensitivity is controlled by a screw that distorts the field of one primary and one secondary.—Automatic Timing & Controls, Inc., King of Prussia, Pa.

Circle No. 14 on reply card

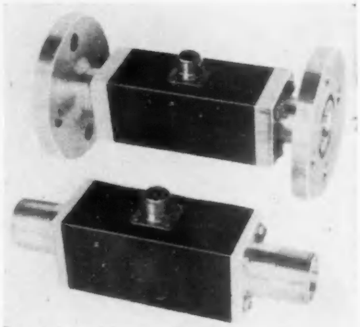


RUGGED PICKUP

A new series of variable reluctance pressure transducers is available in two models. The Model DP-27, above, measures differential pressures, while the Model AP-27 is for absolute pressure. Both feature stainless-steel con-

struction and may be operated with ac carrier systems ranging from 400 to 20,000 cps. Different ranges of coil inductance may be specified for compatibility with the desired carrier system. The DP-27 is available in standard ranges of plus or minus 7.5, 50, 150, 500, and 1,500 psi differential. Ranges for the AP-27 are 0-15, 0-30, 0-100, 0-300, and 0-1,000 psia.—Northam Electronics, Inc., Los Angeles, Calif.

Circle No. 15 on reply card



FOR IN-LINE MOUNTING

Pictured are two versions of a new conductivity cell designed for direct mounting on main process lines of free-flowing liquids. These units operate efficiently at temperatures up to 400 deg F with temperature compensation, and on up to 1,000 deg F without temperature compensation. They require no sampling lines or coolers. The electrodes and a thermistor for temperature compensation are embedded in a cylindrical lining. Principal application is determining the amount of impurities in a free-flowing solution. Available pipe sizes are ⅜ in., ½ in., ¾ in., and 1 in.—Instrument Div. of Robertshaw-Fulton Controls Co., Philadelphia, Pa.

Circle No. 16 on reply card

FOR WEIGHT OR TORQUE

A new line of miniature low-capacity load cells is now available for measuring weight, force, twist, or torque. These units, of the differential transformer type, are enclosed in a shielded metal case and feature ranges of from plus or minus 1 gr to plus or minus 50 lb.—Testing Equipment Sales Co., Murray Hill, N. J.

Circle No. 17 on reply card

Null Indicator wins preference test at IRC. At International Resistance Company, where hundreds of stock resistors are daily subjected to rigid MIL performance tests, an ***ElectroniK*** Null Indicator was recently matched against a spotlight galvanometer for speed, sensitivity and ease of use. The Null Indicator proved superior on each count, and operators indicated a strong preference for it.

ElectroniK Null Indicator is easier to watch, easier to use

THE BIG, clearly legible dial on this all-electronic instrument is easy to read, reduces the chance of error. Even in bright light, there's no need to shade the meter. The needle comes to rest in less than half a second. And there's never "loss of spot" when excessive signal is applied—you always know which direction to go for bridge correction.

The *ElectroniK* Null Indicator goes to work quickly . . . without need for leveling or special mounting. Zeroing is simple, with just a turn of the front-of-panel bar knob. The unit withstands shock and vibration.

The Null Indicator is sensitive enough for all your d-c bridge measurements, and rugged enough for production line work. Order this modern successor to the galvanometer today. Price: $175, f.o.b. Philadelphia.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.

SPECIFICATIONS

Period—less than $\frac{1}{2}$ second
Current Sensitivity—.001 microamp/mm.
Voltage Sensitivity—1 microvolt/mm.
Input Impedance—1000 ohms at max. sensitivity
Overload Rating—1 volt at max. sensitivity
Stability—less than 1 mm. zero shift/hour
Damping—critically damped; independent of external resistance
Terminals—input and ground; for spade, pin or banana plugs
Power—115 volts, 60 cycles
Scale Markings—
−1 to +1 in mm. } over $2\frac{1}{8}$" radius
−4 to +4 in cm. }
Dimensions—$17\frac{5}{16}$" long x $5\frac{3}{8}$" wide x $7\frac{3}{4}$" high
Weight—15 lbs.

Honeywell

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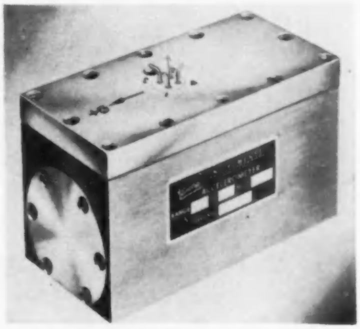
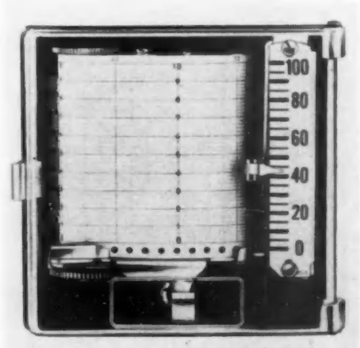


OUTPUTS TO 60 VOLTS

The first of a new line of differential transformer accelerometers, the Model 7-34 has a range of plus or minus 1 to 50 g, and features temperature-compensated damping and infinite resolution. Output at full scale is a maximum of 0.5 volt per volt in, and at zero acceleration is 0.5 percent of full scale. Maximum nonlinearity is 1.0 percent; phase shift at 0 deg is plus or minus 5 deg. Unit takes a standard electrical input of 115 vac at 400 cps. The case is approximately 3.3 in. by 1.9 in. by 1.6 in.—Edcliff Instruments, Monrovia, Calif.

Circle No. **18** on reply card

INFORMATION DISPLAY INSTRUMENTS



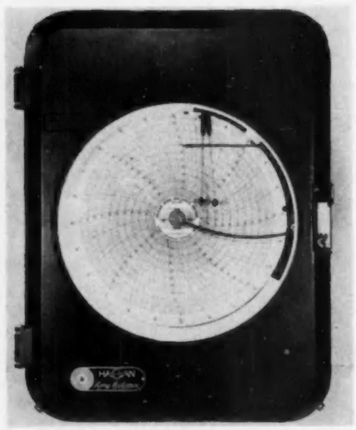
PRESSURE RECORDER

Offered in ranges from 0-3 psi up to 0-60 psi, a new pressure gage records on the 3-in. strip chart shown here. The recording chassis itself is interchangeable and can be plugged in without tools. Three versions are available. One will record and indicate one

NEW PRODUCTS

pressure measurement, another will record two measurements and indicate one, and a third will indicate two measurements and record one.—The Bristol Co., Waterbury, Mass.

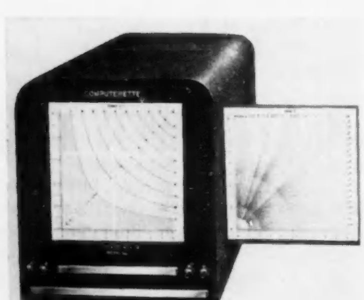
Circle No. 19 on reply card



REMOTE RECORDER

Pictured is an electronic recorder that will receive and record the outputs of four remote meter-operated slidewires. Variables that may be recorded include density, liquid level, and fluid flow. Heart of the newly designed unit is an electronic receiver unit housing an amplifier, input box, servomotor, and slidewire. Four such receivers can be installed in a single recorder. Each is available as an ac servo-operated bridge, a dc potentiometer or a dc voltmeter.—Hagan Chemical & Controls, Inc., Pittsburgh, Pa.

Circle No. 20 on reply card

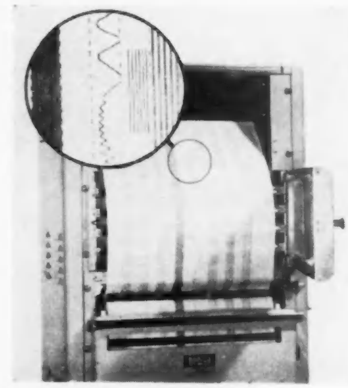


COMPUTING INDICATOR

Intended for both laboratory and industrial use, the Computerette indicates three quantities, two independent variables and any function of them. The instrument consists of two

dc reflecting galvanometers which, with their associated optical systems, project light lines onto a ground-glass screen at the front. The screen itself contains a family of curves representing the third quantity.—Aero Electronics Co., Chicago, Ill.

Circle No. 21 on reply card

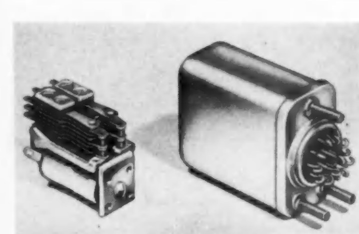


GRAPHIC RECORDER

Designed for digital-data reduction, telemetry output recording, spectrum analyses, and general on-off event displays, this new instrument uses low-cost, wide-dynamic-range electrolytic Faxpaper. Called the RX-48, it will produce up to 450 immediately visible, black-on-white 0.015-in. traces across a 15-in. sheet. Ten chart speeds up to 12 in. per sec increases its flexibility.—Hogan Laboratories, Inc., New York, N. Y.

Circle No. 22 on reply card

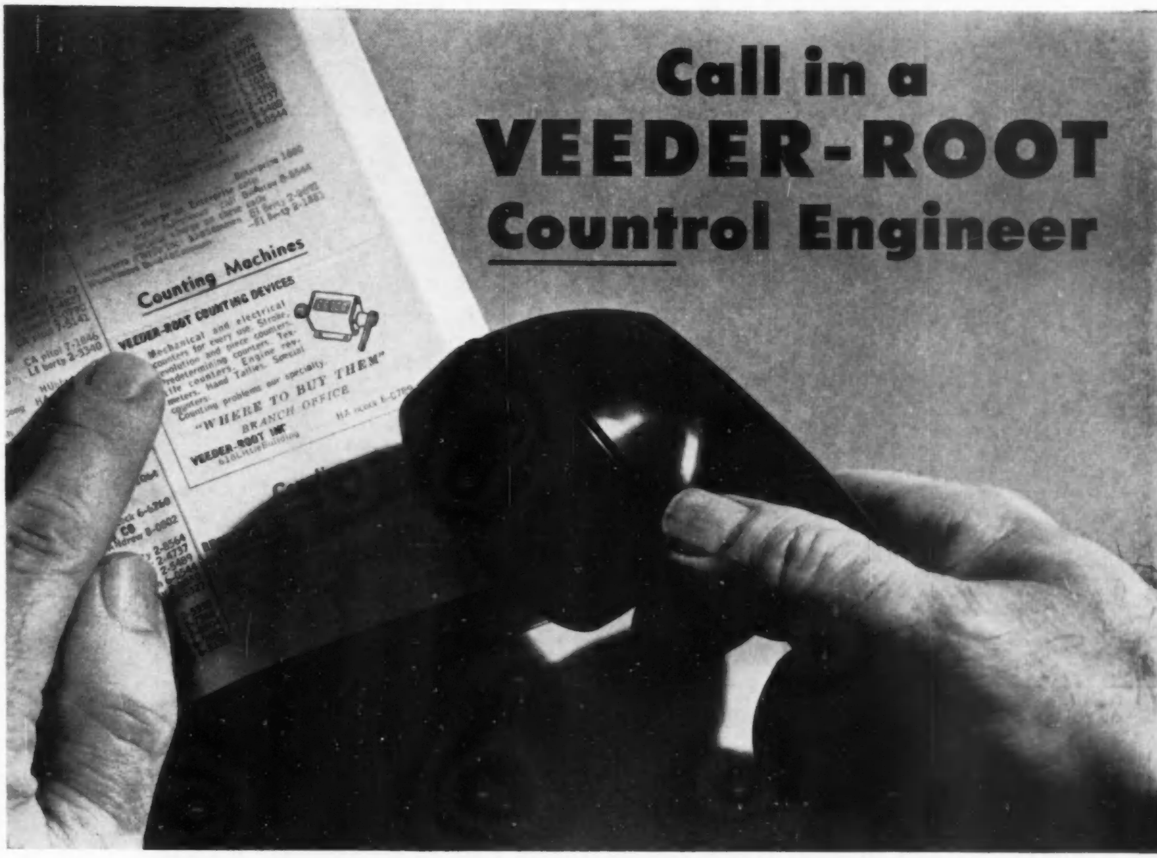
CONTROL DEVICES



RUGGED MIDGETS

A new line of 180 frame midget telephone-type relays features a variety of small-size and low-cost flexing spring contact arrangements. Applications include low-power military, computer, and other commercial equipment. A maximum of 16 flexing contact springs

When it comes to Counting...PUT "first things first!"



"Design them in, when you begin" . . . that's the way to *integrate* Veeder-Root Counters into a new product or process. And the quick way to do this is call the nearest Veeder-Root office and ask for an engineer.

You can count on this man to save you time and money in engineering, purchasing and assembly. For he can often save you the premium cost of a special counter by adapting or modifying a standard counter to do the job you want done . . . whether it's to give you or your customers direct readings . . . remote indication . . . facts-in-figures for production, wage-payment or stock *Count*rol . . . or proof of performance-guarantee.

So when it comes to counting, call the local office or the Hartford plant, JAckson 7-7201.

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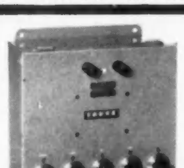
NEW ADDITIONS TO THE MOST COMPLETE LINE OF ELECTRICAL, MECHANICAL & MANUAL COUNTERS



New Electric Predetermining Counter

New Printed-Circuit Data Readout Counter

New Panel-Mount Magnetic Counter with Lock-Key Reset

can be supplied with eight springs in each of two stacks. Minimum power requirements are on the order of 100 mw per pole. Standard coils for open-type relays withstand ambient temperatures to 85 deg C, while special coils handle ambients of 125 deg C.—Struthers-Dunn, Inc., Pitman, N. J.

Circle No. 23 on reply card

EASY TO READ

This new mercury-actuated indicating temperature controller features a dual mounting design and greater readability. Its case permits either flush or wall mounting with no additional hardware. Setting accuracy is improved by the use of a magnifying pointer with two hairlines. An increased dial area with maximum color-contrast simplifies reading. The instrument is accurate to withing 0.5 percent of each of its 10 scale ranges.—The Partlow Corp., New Hartford, N. Y.

Circle No. 24 on reply card

OPERATES AT 600 DEG F.

A small precision switch with a minimum life of 25,000 operations at 600 deg F was recently introduced for jet engines, rocket-powered missiles, and electronic gear subjected to high temperatures. Case, cover, and plunger are molded from a special type of glass-bounded synthetic mica. The switch uses a spdt contact arrangement and has an electrical rating of 10 amp at 125 or 250 vac. A two-piece snap-action spring provides sure contact.—MicroSwitch Div. of Minneapolis-Honeywell Regulator Co., Freeport, Ill.

Circle No. 25 on reply card

air circuitry:

a new term of importance to control engineers.

Air has come of age as a control medium. No longer is it confined to the simple jobs of pushing a clamping device, moving a lever, or blowing chips. No longer is an air circuit just a valve, reservoir, and cylinder. Today the most complex of industrial control problems can and are being solved efficiently with air.

Today, pneumatic circuits can be interconnected. They can be set to control a complex sequence of operations *automatically*. They can be combined with electrical circuits. There is *no* control problem you have that can't be solved successfully with air.

The new role that pneumatic control can play in industrial operations demands a new way of thinking about air control. It demands a new way to describe control by air—a new name that suggests some of its limitless control possibilities. That's why Westinghouse Air Brake Company is now using the term "air circuitry" to describe the application of air control to automation.

Westinghouse Air Circuitry, we realize, has to be more than *just as good* as your present means of control. It has to offer you *extra advantages*. And it does.

Chief among these is its extreme simplicity. The devices themselves are uncomplicated mechanical devices. They have few moving parts. They are easy to service by any mechanic. The circuit connections are made with pipe—and what could be simpler than that!

This extreme simplicity brings with it other important "pluses" for air circuitry. The simple equipment is unusually reliable—there are few moving parts to wear out or get out of adjustment. The devices are sturdy and durable. They require very little maintenance. What maintenance there is can be handled without the services of highly trained technicians.

Above all, remember: no means of control is as *safe* as air.

Air circuitry can help you simplify your control problems. It can help you get accurate answers to your automation problems on any industrial machine . . . in any industrial process. And Westinghouse Air Brake Company can help you with the engineering of a suitable system. Westinghouse has been in the control engineering business for 80 years now. It has been at the forefront of the development and improvement of air control equipment and its applications.

For more information on Westinghouse Air Circuitry—how it has helped other companies, how it can help you—write for your copy of "Basic Pneumatic Control," or call our nearest sales office.

WESTINGHOUSE AIR BRAKE COMPANY, INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PA.

POWER SUPPLIES

FOR TRANSISTOR CIRCUITS

This closely regulated dc power supply, designed for use with transistor circuits, has a continuously variable output of 0 to 60 vdc, at 3-amp maximum. No derating of output current or of regulation and ripple specifications is necessary from 1 to 60 vdc. Ripple and internal noise are below 1.5 mv rms. Designated Model 6-3MB, the instrument features very low output impedance and a fast recovery time, and is built to fit a standard 19-in. relay rack.—Dressen-Barnes Corp., Pasadena, Calif.

Circle No. 26 on reply card

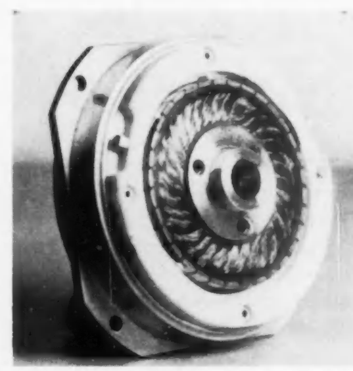
EXTENDS TUBE LIFE

Designed to extend the life and reliability of complex vacuum tubes in sensitive electronic equipment, the type EM10018 Automatic Voltage Regulator is fully automatic when used with external contactors and on-off controls. When the equipment is energized, voltage to the tubes is run up gradually to minimize surge strain on the filaments. A control circuit automatically maintains a stabilized output voltage level, preset to operate the equipment at its peak efficiency. Voltage run-up takes 5 to 14 sec, de-

pending upon the output voltage setting and on whether the unit has been in operation immediately prior to the run-up. Input is 208 volts plus or minus 10 percent, single phase, 57-63 cps; output is 208 volts nominal, 0-163 volts unregulated, 163-208 volts adjustable regulated, 45 amps at 40 deg C.—The Superior Electric Co., Bristol, Conn.

Circle No. 27 on reply card

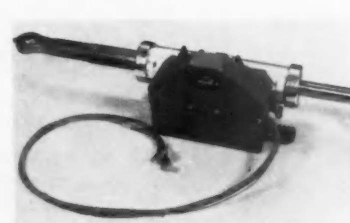
FINAL CONTROL ELEMENTS



TORQUE MOTORS

A complete line of dc torque motors is now available for use in servo systems requiring direct drive and a minimum size, weight, and response time. Using direct drive, these motors attain angular accelerations up to 4,000 rad per sec. Sizes range from 0.05 lb-ft to 500 lb-ft; basic diameters, from 1.9 in. to 30 in.; lengths, from 0.5 in. to 6.2 in. Matching rotary amplifiers are also available.—Inland Motor

Circle No. 28 on reply card



VERSATILE SERVOVALVE

Pictured is a new powered-flight-control servo-valve of the multiple-input type, designed to operate a tandem hydraulic cylinder. The unit, called

Lambda power supplies have varied uses in the North Carolina Works of the Western Electric Company. This representative installation includes among its components eight Lambda Com-Pak power supplies.

Western Electric uses standard Lambda supplies to power defense system tests

NEW **COM-PAK®** POWER SUPPLIES SAVE VALUABLE PANEL SPACE
Models through 1.5 amperes
Three voltage ranges: 0-200, 125-325, 325-525 VDC

C-200 series–	200 MA–5¼"	panel height–from	$159.50
C-400 series–	400 MA–5¼"	panel height–from	244.50
C-800 series–	800 MA–7"	panel height–from	315.00
C-1500 series–	1500 MA–8¾"	panel height–from	550.00

Lambda power supplies provide Western Electric Company with power for testing components of the United States continental air defense system.

These are standard Lambda models, supplied from stock, with front-panel modifications only.

Available for immediate delivery, Lambda power supplies from stock also are being used in major rocket and missile programs.

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the Hydomat, features three modes of operation:

- manual, in which mechanical signals initiated by the pilot operate the valve in the conventional power-control manner;
- autopilot, in which electrical signals created by electronic amplifiers operate the valve as a conventional electrohydraulic servovalve; and
- damper, in which mechanical signals operate the valve as in the manual mode, with superimposed electrical signals to provide damping for improved airframe stability.

For safety in the autopilot mode, the pilot can override the electrical signal by simply overcoming a predetermined threshold force. Normal flow rates range from 0.5 to 10 gpm.—Hydraulic Research & Mfg. Co., Burbank, Calif.

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DIGITAL EQUIPMENT

VERSATILE PRINTER

Called the Magnityper, this new alphanumeric high-speed printer features input adaptability to any source of digital data. Integral housing of the mechanical printing assembly with the electronic components is said to provide space and power economy. Its use of solid-state devices, combined with its modular construction, assures high reliability and ease of maintenance. The unit has a 120-column storage system and will print 10 lines of alphanumerical characters per second. Up to 63 different characters are available.—Potter Instrument Co., Inc., Plainview, N. Y.

Circle No. 30 on reply card

VOLTAGE-TO-DIGITAL

Priced at $9,500, this new high-speed electronic voltage-to-digital converter, the Model B-617 DATRAC, converts input voltages to four binary-coded decimal digits at the rate of 3,700 conversions per second. Standard full-scale input ranges of plus or minus 10, 100, and 1,000 volts are readily switched by an external trigger pulse. —Epsco, Inc., Boston, Mass.

Circle No. 31 on reply card

TYPING CALCULATOR

Designed primarily for business-order and invoice preparation, this new Electronic Typing Calculator can be programmed to automatically retain and type out gross sales, taxes, shipping charges, invoice totals, or other selected accumulations on a daily basis. Priced at approximately $5,600, the unit consists of an electric typewriter, a 10-key companion keyboard, a magnetic-core memory, and a program-reading device. Numerical information, keyed in on the companion keyboard, can be added, subtracted, multiplied, rounded off, or held in the memory unit for later processing.—International Business Machines Corp., New York, N. Y.

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IMPORTANT MOVES BY KEY PEOPLE

A. C. Hall Moves to Martin; Kock Advances at Bendix

As the last copies of the February issue of CONTROL ENGINEERING rumbled through the mail chute, Albert C. Hall, the *Control Personality* for the month (page 23), completed negotiations with The Martin Co. to join the Baltimore firm as director of research. Succeeding Hall as general manager of the Bendix Research Laboratories Div. of Bendix Aviation Corp. is Winston E. Kock, formerly chief scientist of the Systems Div. of Bendix, who takes on the additional title of division director.

At Martin, Hall will oversee the technical end of the Titan ICBM project. He comes to Martin after eight years at Bendix, four of them as head of the Detroit research laboratories. He taught at MIT from 1937 to 1950, and during this period founded and became the first director of the institute's Dynamic Analysis & Control Laboratory. Kock has been chief scientist of the Bendix Systems Div. since 1956. Earlier he served as director of research for the Baldwin Piano Co. and director of acoustics research and of audio and video systems research for Bell Telephone Laboratories. He developed the electronic organ for the former company; for the latter, he developed the waveguide microwave lens, the artificial dielectric lens, and the acoustic lens.

Both Hall and Kock hold Eta Kappa Nu's Outstanding Young Engineer award, and both are fellows of the IRE.

Other Important Moves

▶ **H. Perry Smith**, assistant director of research for Associated Spring Corp. since early last year, has succeeded **Franz P. Zimmerli**, who retires as director after more than 30 years with the company. At the same time, direction of all research activities shifts from Plymouth, Mich., to a new research center under Smith, at the company's home base in Bristol, Conn. Zimmerli came to ASC as director of research in 1955. Before that he had been with the company's Barnes-Gibson-Raymond Div. as chief engineer. His contributions to the art of spring-making and to the science of metallurgy are outstanding. Smith

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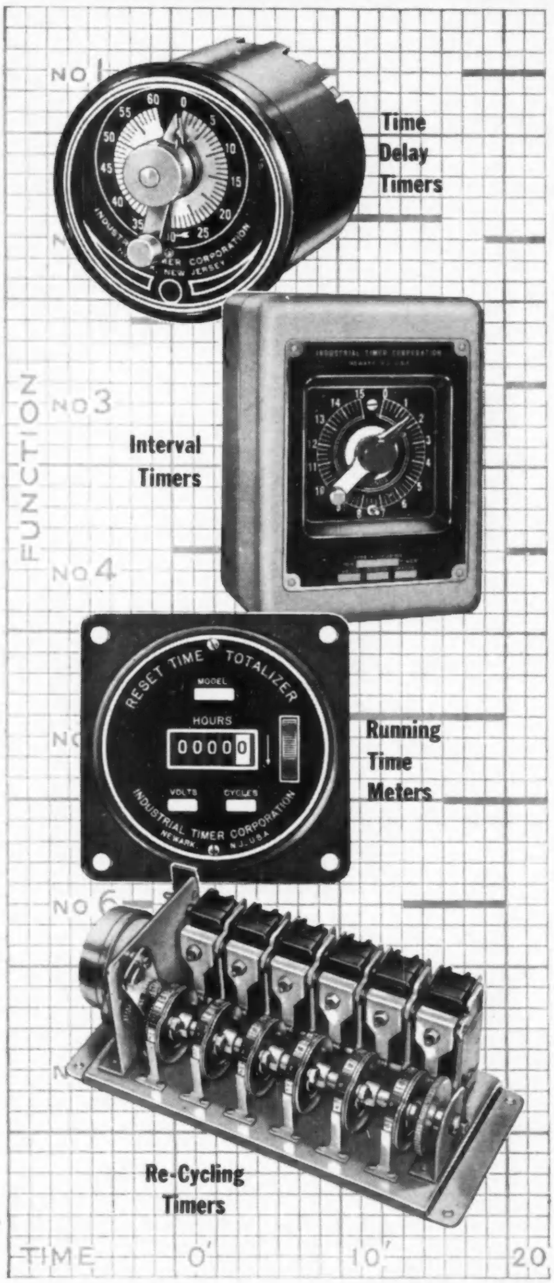

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most recently was with Underwood Corp. as manager of the General Research Laboratory at Hartford, Conn.

► Two significant appointments by the Leland Electric Div. of American Machine & Foundry Co. spotlight **Joseph E. Mulheim,** named director of aircraft products engineering and manufacturing, and **Hayes Crapo,**

J. E. Mulheim

Hayes Crapo

named chief engineer of aircraft products. Mulheim joined Leland in 1955 as chief engineer; before that he held key design and administrative posts in the aircraft electrical accessories field. Crapo, his successor, joined Leland as a design engineer in 1956; earlier, he had been with Westinghouse.

► **Stanford B. Spracklen,** co-developer of the first industrial gas chromatograph for continuous stream analysis and control, has been named associate director of research and engineering for the Process Instruments Div. of Beckman Instruments, Inc. His specific area will be continuous-operating analytic instrumentation for the process industries, particularly gas chromatographs and their application to chemical, petrochemical, and petroleum plants. Two appointments in the Scientific Instruments Div. are akin to Spracklen's. They involve **James E. Stewart,** named senior chemist in infrared applications, and **Don W. Carle,** named chief project engineer of the Gas Analyzer Section. Spracklen for 13 years was supervisor of instrument R&D for Union Carbide Chemicals Co., where the gas chromatograph was developed. Earlier he was with Cities Service and Atlas Powder Co. Stewart, a physicist, comes from the National Bureau of Standards, where he did work in infrared spectroscopy. Carle, formerly a research chemist with Stauffer Chemical Co. of Torrance, Calif., will oversee design and development of gas chromatographic instrumentation.

► Tracerlab, Inc., has appointed **George Manov,** formerly with the AEC and a pioneer in the development of isotope applications, technical director of the Reaction Monitor-

ing Center in Richmond, Calif. About his appointment, Tracerlab President **S. S. Auchincloss** had this to say: "Isotope ultilization has proved to be the fastest-growing and most profitable development in the nuclear field, far outstripping atomic power. As competition increases with the rapid growth in the use of isotopes, Dr. Manov's knowledge in the nuclear field and his wide acquaintance with isotope applications will certainly help Tracerlab maintain the position of leadership it has acquired in the applied radiation business."

► The new vice-president of engineering and manufacturing of Non-Linear Systems, Inc., is **William C. McDonald**, who has been works manager since 1957. A physicist, and an easterner, McDonald was connected with MIT's Lincoln Laboratories, Cornell Dubilier Electrical Corp., and Hartford Empire Co. before heading west to join Non-Linear Systems as director of research in 1956.

► **Cuthbert C. Hurd**, director of automation research for IBM, has been elected president of the board of trustees of the Foundation for Instrumentation Education & Research. Other new officers of the board: **Robert J. Jeffries**, president of Data-Control Systems, Inc. (CtE, Feb., p. 169), vice-president; **W. W. Garey**, publisher of CONTROL ENGINEERING, treasurer, and **Rowland Burnstan**, president of Borg-Warner International, secretary.

Obituaries

Leland K. Spink, 58, engineer in charge of flow measurement at The Foxboro Co., at Foxboro, Mass.

James H. Critchett, a retired vice-president of several divisions of Union Carbide Corp., at his home in Orleans, Mass.

Basil M. Goldsmith, 49, material control manager of the Industrial Tube Div. of Allen B. Du Mont Laboratories, Inc. His home was in Rutherford, N. J.

A Correction

Allen Easton is vice-president of the new Marketing Div. of General Transistor Corp., and Jerome Fishel is assistant vice-president and manager of applied electronics. These changes were reported incorrectly in January.

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(100) HIGH-PRESSURE CYLINDERS. The Oilgear Co. Bulletin 71000, 8 pp. Covers a complete line of all-steel, double-acting hydraulic cylinders for pressures up to 2,000 psi. Units are classified according to the type of mounting provided. Also includes a table of pushing and pulling forces for fluid pressures from 300 to 2,000 psi.

(101) HIGH-SPEED INSTRUMENTS. George Kent, Ltd. Publication 993, 8 pp. Introduces the Commander line of high-speed electronic instruments for indicating, recording, and controlling applications. Design and construction features are discussed with particular emphasis on front and back accessibility. Back cover provides dimensions and mounting details.

(102) MILL REGULATOR. Reliance Electric & Engineering Co. Bulletin K-2503, 6 pp. Describes the dual-circuit VSMR Mill Regulator, an electronic fail-safe unit that provides precise regulation of line speed, voltage, and tension for all continuous-process industries. Photos illustrate the various components.

(103) "ADD-SUBTRACT" COUNTER. Eagle Signal Corp. Bulletin No. 740, 2 pp. Provides data on the operation and application of a new counter for count control between two limits, actuated by "add" and "subtract" pulses. Dimension drawings, wiring diagram included.

(104) ENGINE INDICATOR. Kistler Instrument Corp. Bulletin EA-114, 4 pp. Photos and typical pressure diagrams illustrate the versatility of the SLM Engine Indicator, a combined electronic pressure indicator and engine analyzer.

(105) ALARM SYSTEM. Richardson Scale Co. Data Sheet 5703, 2 pp. Explains the operation of a new alarm system for automatic protection against coal-supply failure in pulverizer or stoker-fired operations. Drawings illustrate a magnetic impulse switch and the control circuitry for the entire system.

(106) ROTARY COMPRESSORS. American Brake Shoe Co. Booklet, 8 pp. Uses cutaway diagrams to explain the operating principles of a new line of rotary air compressors. Describes special features and offers detailed mounting specifications.

(107) COMPUTER APPLICATION. Computer Div., Bendix Aviation Corp. Application Report No. 5, 4 pp. A detailed, illustrated report on how the Bendix G-15 general-purpose digital computer saves both time and manpower on the design of complex cams.

(108) INSTRUMENTS FOR pH. Beckman/Process Instruments Div. Bulletin 5400, 8 pp. Provides detailed descriptions and specifications on a line of industrial pH instruments, electrodes, accessories.

(109) ELECTRIC MOTORS. Franklin Electric Co., Inc. Catalog No. P-86012, 8 pp. Illustrates a line of application-engineered fractional-horsepower motors. Special mention is given to the company's submersible deep-well motors and submersible explosion-proof motors. Table provides service factors on standard motors.

(110) PNEUMATIC INSTRUMENTS. U. S. Gauge Div. of American Machine & Metals, Inc. Catalog 510, 16 pp. Describes a complete line of indicating controllers for temperature and pressure control, transmitters for remote indication, and various receiver gages. Introduces some new pressure elements and includes tables of ranges, element characteristics, and bulb lengths.

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Analytic Systems Co. Bulletin 60, 4 pp. Describes the operation, specifications, and applications of the Model 60 Ultraviolet Unit for continuously analyzing components in a flowing gas or liquid. Various modifications and accessories mentioned.

(112) SILICON RECTIFIERS. Transitron Electronic Corp. Data Sheets TE-1351B and 1351B-1, 2 pp. each. Provides maximum ratings and specifications on recent additions to the company's expanding line of axial-lead silicon rectifiers for military and industrial applications.

(113) LOW-COST INFRARED. Beckman/Scientific Instruments Div. "Infrared Notes", Vol. 3, No. 2, 4 pp. Informative, illustrated bulletin features the low-cost, double-beam IR-5 Spectrophotometer for routine infrared analyses. Also provides data on the applications of the IR-4 model, and an index of company literature on spectrophotometry, gas chromatography, and pH.

(114) QUALITY TRANSFORMERS. Hermetic Seal Transformer Co. Catalog No. 102, 28 pp. Covers standard and custom transformers, filters, reactors, and toroids for applications requiring hermetically sealed components. Tables of electrical specifications and case dimensions are included.

(115) SYNCHRONOUS CONVERTER. George Kent, Ltd. Publication 994, 12 pp. Reviews the principal features and specifications of a new synchronous converter and offers eight full pages on application. Diagrams illustrate some of the more common modulating and demodulating circuits.

(116) BOILER CONTROLS. Blaw-Knox Co. Bulletin 1038, 12 pp. Using a 900,-000 lb/hr boiler as an example, the bulletin gives a detailed description of the combustion controls and a completely automatic soot blowing system. A 2-page schematic shows a simplified hook-up of all components from the primary elements to the pneumatic actuators.

(117) POWER SUPPLIES. Hyperion, Inc. 4-page folder. Describes a new line of transistorized power supplies, both regulated and unregulated. Emphasizes such features as reduced size and high current capabilities.

(118) TIMING MOTORS. Cramer Controls Corp. Bulletin PB-117, 2 pp. Offers complete technical, operational, and design data on the company's Series 117 permanent magnet synchronous motors. Specifications on five versions include torque ratings, speeds, shaft dimensions, etc.

(119) VARIABLE AUTOFORMER. I-L-S Instrument Corp. Form 6240, 2 pp. Photos, drawings, and specifications outline the features of a new explosion-proof variable autoformer for hazardous areas.

(120) RUGGED CONNECTORS. De-Jur-Amsco Corp. Brochure, 4 pp. Includes general information, dimension drawings, and a table of electrical and mechanical ratings for a new line of microminiature connectors.

(121) TEMPERATURE REGULATORS. Spence Engineering Co., Inc. Bulletin No. 1012, 6 pp. Describes two new series of steam regulating valves with pilots for both fast and slow heat exchangers. Selection tables and line drawings of typical applications are also shown.

(122) ADJUSTABLE SPEED DRIVE. Louis Allis Co. Bulletin 2000, 12 pp. Stresses design features, installation, and applications of a new variable-voltage dc drive that uses ac as its power source.

(123) CONTROLLED-VOLUME PUMPS. Milton Roy Co. Bulletin No. 1157, 2 pp. Specifies capacities, pressures, and construction materials of a leakproof controlled-volume pump for metering corrosive, obnoxious, or toxic chemicals. Also describes the mechanical actuation for correcting the volume delivered per stroke.

(124) POSITIONING GEARMOTORS. The Jordon Co., Inc. Bulletin J101. Includes new information on the Shaftrol and Valvetrol shaft-mounted gearmotors for positioning valves, drives, pumps, and other equipment. Specifications on a new digital control system are also included.

(125) TORQUE MOTORS. Inland Motor Corp. Catalog, 42 pp. Starts with a general discussion of the advantages of permanent-magnet dc torque motors and their overall specifications. Sixteen different types are described and illustrated with dimension drawings, performance curves, and rating tables.

(126) ACCELERATION TESTING. The Rucker Co. Bulletin S-1. Covers the precision testing of simulated operational g-loadings using the company's centrifuge acceleration test machines.

(127) SOLENOID DATA. G. H. Leland, Inc. Bulletin 1057-S, 12 pp. Contains dc torque charts of basic solenoid designs, along with line drawings of each stock model. One page describes the B6162B full-wave rectifier and provides an electrical data chart on its performance.

(128) FLOW RATE ALARMS. Brooks Rotameter Co. Bulletin 165, 4 pp. Both magnetic and electronic fluid flow rate alarms are described in this bulletin. Covers mechanical and electrical features, specifications, and operating principles.

(129) INSTRUMENT VARIETY. The Hays Corp. Publication 57-687-297, 12 pp. This condensed catalog is actually a digest of specifications on instruments for transmitting, indicating, recording, and controlling process variables such as temperature, pressure, flow, and level. Also includes gas analysis equipment.

ABSTRACTS

Putting Error to Work

From "Compensating Saturation in Feedback Control Systems by Excess Error Storage" by S. S. L. Chang and R. W. Archbald, both of New York University. AIEE Transactions Paper No. 58-92, presented at the Winter General Meeting, New York, N. Y., February 2-7, 1958.

A major cause of transient saturation in feedback control systems is the use of lead, or lead-lag, networks. While such networks are necessary to improve speed of response and stability, they cause sharp peaks in the forcing function. Since these peaks are many times the normal value of the forcing function, the system is temporarily saturated, and responds sluggishly, often with large overshoots. Figure 1A, reproduced below, shows the block diagram of a typical Type II system with simple limiting. Transfer functions of the compensating network, G_c, and controlled system, G_m, are given as:

$$G_c = \frac{0.2(1 + 5.2s)}{1 + 0.2s}$$

and

$$G_m = \frac{2.5}{s^2}$$

For a large step input, the plotted response of this system shows that while the output function $f_1(t)$ is a sharp peak, exceeding 150 volts, its effective portion $f_2(t)$ cuts off at 10 volts. As a result, the controlled system fails to reach the desired initial speed, and a large error tail is produced.

The added storage element (the author's Figure 1B) stores any input signal in excess of the saturation limit and applies it to the controlled system immediately after the input signal drops below the saturation limit. Here the plotted response curves show that the effective forcing function $f_2(t)$ remains at a maximum value some time after $f_1(t)$ has reversed sign. This extended duration partially compensates for the lost magnitude, and system error is considerably reduced.

Two alternative arrangements for excess signal storage are proposed: one for the case where the output of the nonlinear element is accessible, the other for the case where this output is not accessible or can be obtained only at appreciable cost. This second arrangement simply provides for the addition of a second nonlinear element, matched to the existing one so that they both saturate at the same time. With idealized saturation curves, operation of both arrangements is identical.

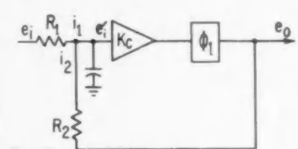


Fig. 7

The last figure (the author's Figure 7) shows the details of the circuit developed for the storage of the excess error signal. Physically, ϕ_1 represents the saturating limits of the amplifier, and the time constant is obtained by shunting capacitor C across the input terminals of the amplifier. While the amplifier K_c and capacitor C look very much like those found in most feed-

Fig. 1A.

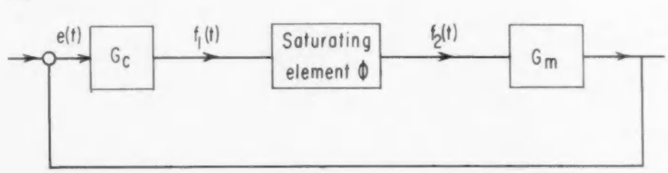
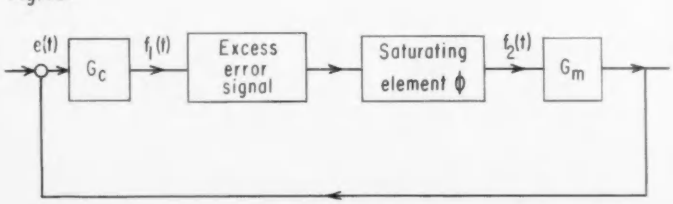


Fig. 1B.



back control systems, there are two important differences: the saturating limits of the amplifier are matched and the value of C is extremely large. The time constant of C is comparable to $1/\omega_0$, where ω_0 is the gain crossover frequency in rad/sec. For relatively small inputs, the system is unsaturated, and the effective time constant of the storage circuit can be made negligible by selecting a large value for K_c.

Techniques for analyzing response and signal stability are also presented.

Controls Up To 60 Watts

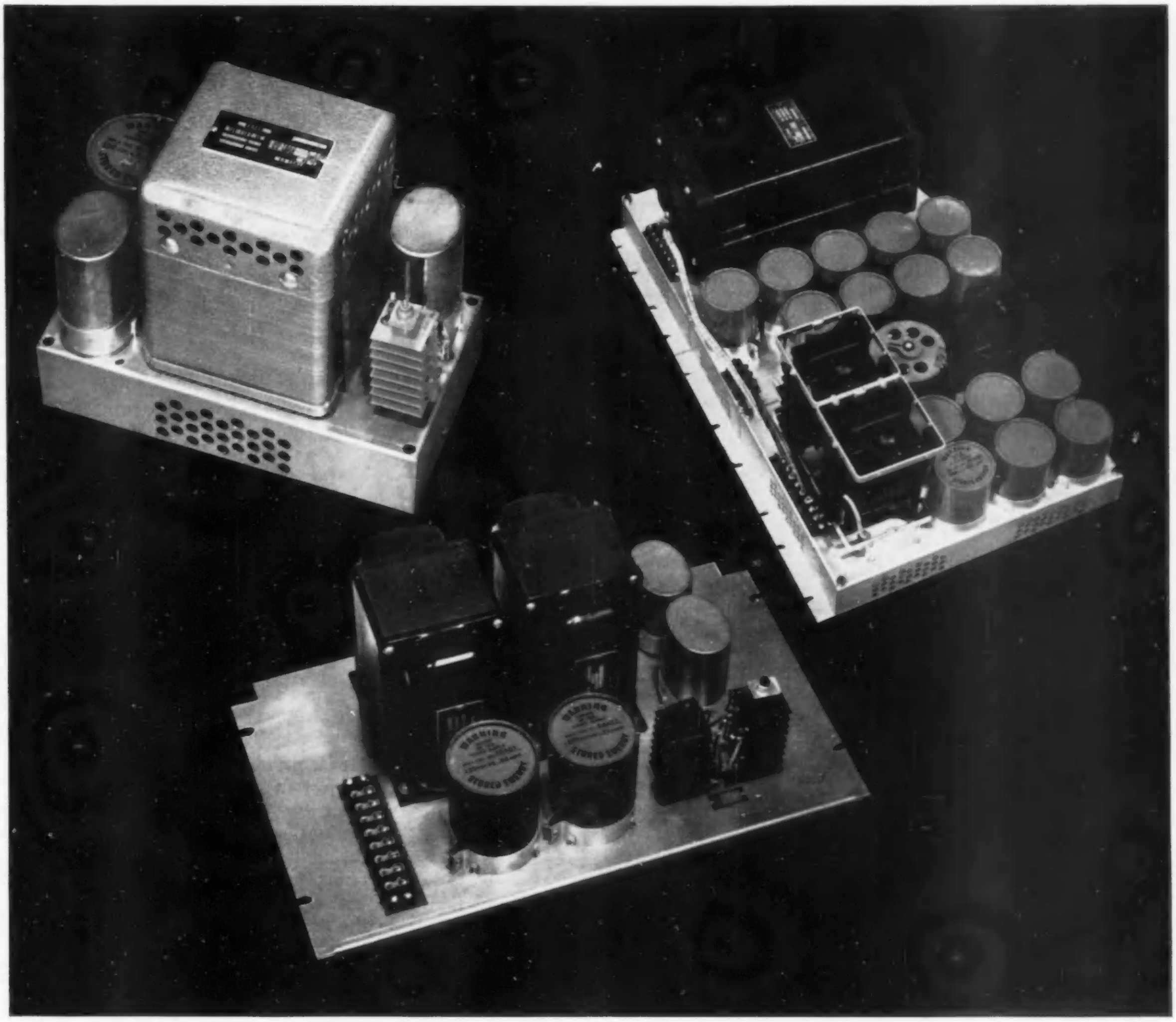
From "A Thermionic Rheostat for Automatic Control" by E. G. Hopkins, New South Wales University of Technology. Presented in the Proceedings of the IEE, Paper No. 2288M, April 1957 (104A, p180).

This paper describes an experimental thermionic rheostat called an "evatron", in which the spacing between two thermionic cathodes is controlled by rotating the tube itself while one cathode is held stationary by an external permanent magnet. Enclosed in a glass envelope, the tube will control ac loads of up to 60 watts when operated as a series resistor from a 240-volt line. Three experimental closed-loop systems are used to demonstrate the versatility of this device. These systems include a simple position control, a velocity-integral control for moving materials, and an airflow control. In each case a mechanical error signal initiates control action.

Aircraft Engine Controls

From "The Electrical Control of Power Plants" by G. M. Sturrock, Ultra Electric, Ltd. Paper presented at the Sixth Anglo-American Aeronautical Conference, Folkestone, England, Sept. 9-12, 1957.

After a brief introduction to the problems of electrical and electronic engine controls, the author examines a specific commercial controller, the Electric Throttle used in Britannia aircraft. Consideration is given to the numerous requirements that beset the designer: in general, reliability, bulk, weight, ruggedness, and performance. Operating principles are discussed, together with the philosophy of safety that evolved. The description of the magnetic amplifier in the system is written so that anyone with even an elementary knowledge of electrical and magnetic theory can understand it.



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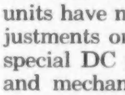

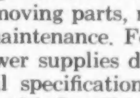

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NEW BOOKS

Monthly Computer Roundup

COMPUTERS. *A monthly bibliographical bulletin on electronic computers. Published by The Bureau of Technical Information, Iota Services, Ltd., 38 Farringdon St., London, E.C.4, England. About $18 a year.*

Published in England on the first of each month, this bulletin provides a fairly complete record of everything available — in Great Britain, the United States, and elsewhere — on computers and their application. Books, articles, technical films, and patents are covered, as well as reports, exhibitions, and trade literature. Many of the entries are accompanied by a short abstract.

The scope seems to be design and application literature on analog and digital equipment, with a little more specific treatment of the application material.

Paper Controls

PULP AND PAPER MILL INSTRUMENTATION. *E. J. Cole and M. Todd. 117 pp. Lockwood Trade Journal Co., Inc., 15 West 47th Street, New York. $3.50.*

Intended as an elementary guide for paper-mill instrument mechanics, this slim volume gives the qualitative principles of control and controllers, fundamentals of paper- and board-making, and detailed descriptions of specialized pulping processes.

Simply and nonmathematically written, it takes the beginner in paper mill instrumentation through the methods of measurement of variables. Temperature, pressure, flow, pH, conductivity measurements are all briefly dealt with, and are followed by an explanation of automatic control covering proportional control with both integral and derivative action. Here the book takes its one dive into mathematics, only to be bedeviled with typographical errors.

Following these introductory sections are two chapters on paper- and board-making, indicating the points at which controllers and recorders are normally installed.

The final sections deal in detail with individual processes, such as the kraft pulp mill, the sulphite pulp mill, continuous semi-chemical pulping, bleaching plants, and the groundwood mill. For each, the recorder and controller are located in a flow diagram and their functions described.

Written by paper-mill instrument men, this book provides good background material for instrument trainees in the paper industry. The concluding chapters provide a run-down on the organizations and duties of a mill instrument department, and an appendix shows how such a department should be developed.

British Contribution

PRINCIPLES OF ELECTRICAL MEASUREMENTS. *H. Buckingham and E. M. Price. 600 + xxiii pp., illustrated. Published by Philosophical Library, Inc. New York City, 1957. $15.00.*

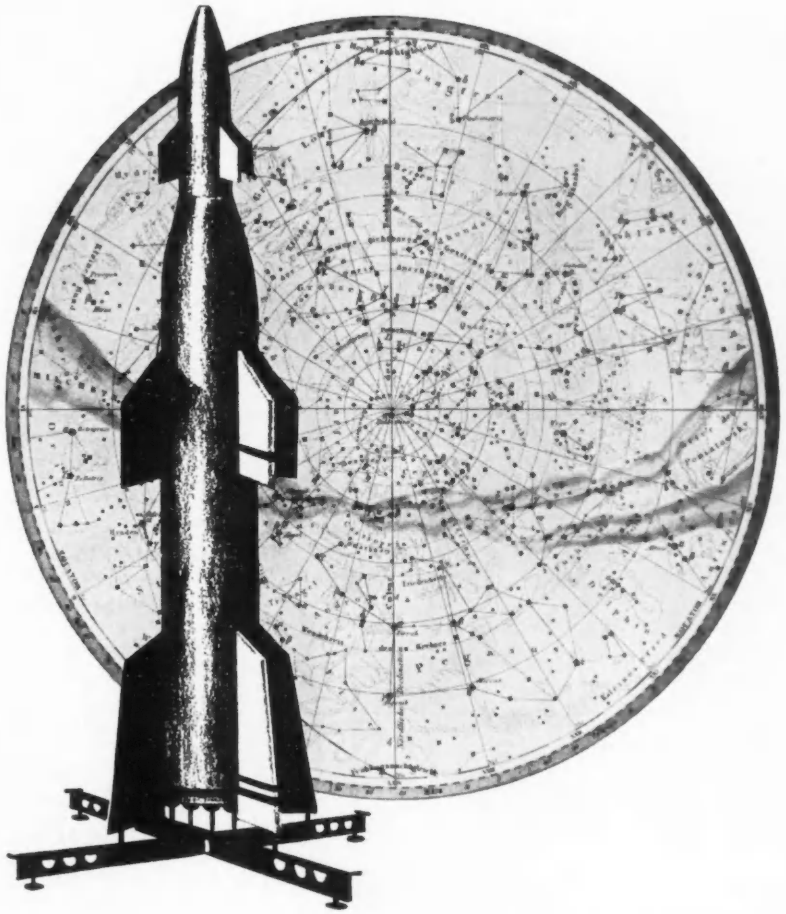
Though this book was designed primarily for advanced electrical engineering students and those preparing for Part III of the British IEE Examination and other certifications, it can be a valuable addition to an instrument engineer's library.

Chapters I and II cover deflectional instruments and various application techniques, a fitting approach to the subject in view of the fact that most electrical engineers make their first contact with electrical measurements through the medium of indicating instruments. In Chapter III, on potentiometer measurements, some of the less common but more accurate techniques are considered.

Before the next subject, bridge methods, the authors have inserted a chapter on measuring systems, dimensions, and standards. At first this may appear to disrupt the continuity of the book, but it soon proves its value in providing a fuller understanding of the material that follows.

The chapter on bridge methods describes their advantages and limitations, and outlines some of the less common bridge network developments. A chapter on oscillations and vibrations provides an excellent review of the differential equations involved and their usefulness in studying the transient response of various circuits. The cathode rays oscillograph and its application are also treated here.

Electronic devices and resonance methods appear in Chapters VII and VIII. These are followed by separate chapters covering measurements in power systems, integrating meters, instrument transformers, and magnetic measurements. The last chapter covers the electrical measurement of some nonelectrical quantities and illustrates some of the more important techniques in this class.



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Fourth International Instrument Show, Caxton Hall, Westminster, London, S.W. 1 — March 24-29

American Power Conference, 20th Anniversary Meeting, Hotel Sherman, Chicago — March 26-28

APRIL

Instrument Society of America (New Jersey section), Tenth Annual Symposium–Control Systems Engineering–Hotel Essex House, Newark, N. J. — April 1

American Society of Mechanical Engineers, Fourth IRD Conference, University of Delaware, Newark, Del. — April 2-4

Institute of Radio Engineers, 10th Southwestern Conference & Electronics Show, St. Anthony Hotel and Municipal Auditorium, San Antonio, Tex. — April 10-12

American Institute of Electrical Engineers, Automatic Techniques Conference, Hotel Statler, Detroit — April 14-16

22nd Annual Machine Tool Electrification Forum, Hotel Statler, Buffalo, N. Y. — April 22-23

Electronic Components Conference, sponsored by IRE, AIEE, Ambassador Hotel, Los Angeles. — April 22-24

MAY

Instrument Society of America, Fourth National Test Instrumentation Symposium, Park Sheraton Hotel, New York — May 4-7

Institute of Radio Engineers, Western Joint Computer Conference, cosponsored by AIEE and ACM, Ambassador Hotel, Los Angeles — May 6-9

Instrument Society of America, Fourth National Symposium on Instrumental Methods of Analysis, Shamrock-Hilton Hotel, Houston — May 12-14

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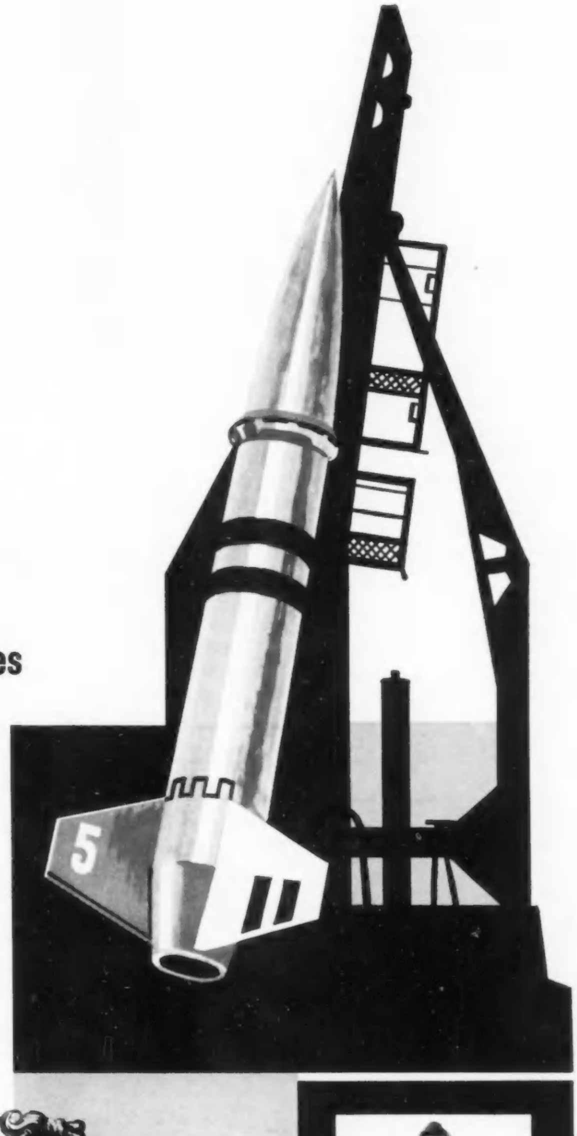
Instrument Society of America, National Conference on Power Systems, New York — May 21-23



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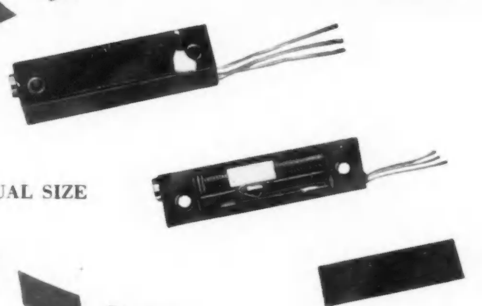

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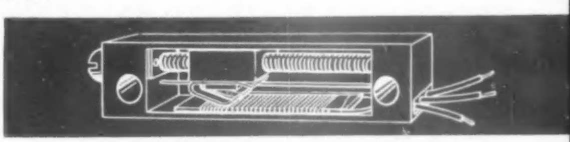

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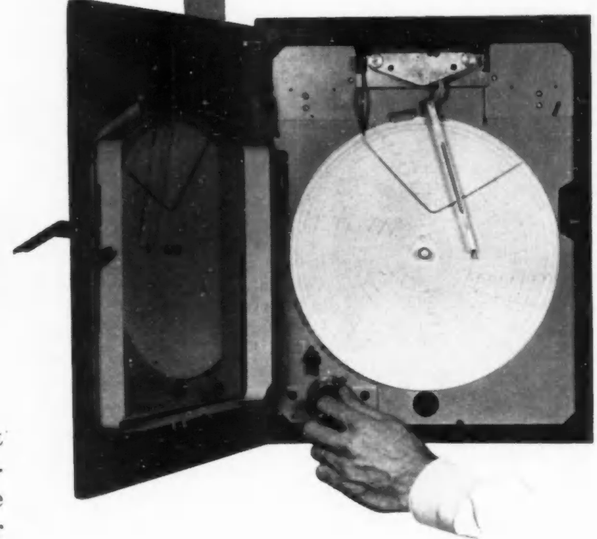

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